NASA Tech Briefs

National Aeronautics and
Space Administration

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Life Sciences

INTRODUCTION

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National Aeronautics and
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Multiple-Pump Lasers

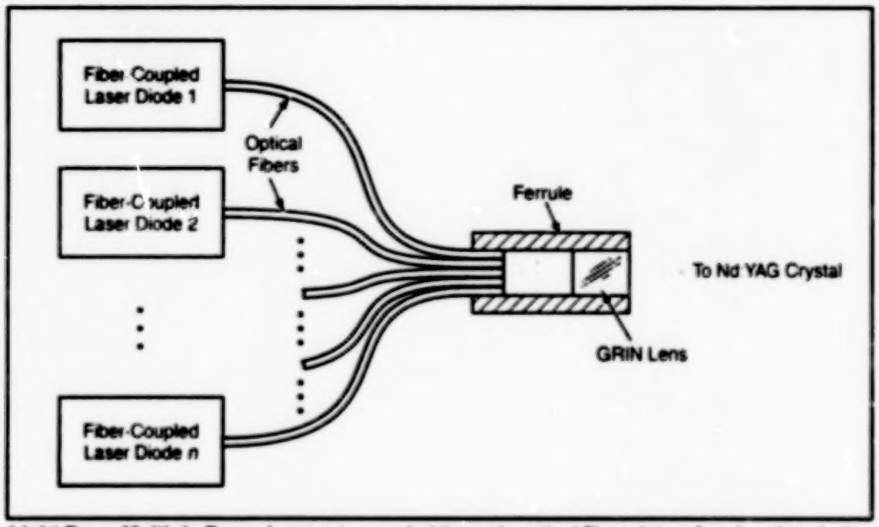
Fiber-optic coupling is exploited to increase reliability without excessive complexity.

NASA's Jet Propulsion Laboratory, Pasadena, California

A conceptually simple, effective scheme for reliable, high-power pumping of neodymium:yttrium aluminum garnet (Nd:YAG) lasers (and perhaps also other solid-state lasers) has been devised. Heretofore, it has been common practice to pump a Nd:YAG crystal by use of a single diode laser. However, diode lasers are not reliable enough to support long-life, high-power operation. If multiple diode lasers could be used to pump a single Nd:YAG crystal, then laser operation would be less degraded by the deterioration or failure of a single diode laser.

One alternative scheme for coupling light from multiple laser-diode pumps into a single Nd:YAG crystal would involve the integration of multiple laser diodes, along with relatively complicated optics, onto a single chip. In such an arrangement, it would not be possible to change the number of pumps. Moreover, the pumps would not be isolated from each other, so that failure of one could adversely affect the operation of the others.

In contrast, the present scheme affords optical isolation of the pump lasers from each other, is amenable to addition or removal of pump lasers, and involves relatively simple optics. The output ends of the fibers of multiple independent fiber-coupled laser diodes are bundled together in a ferrule (see figure). A gradient-index-of-refraction (GRIN) lens in the ferrule combines the multiple pump beams into a single beam aimed into the Nd:YAG crystal. The failure of one laser diode does not affect the operation of the others, and the light from the others continues to pump the Nd:YAG crystal.



Light From Multiple Pump Lasers is coupled through optical fibers into a ferrule, wherein the individual pump beams are combined.

This work was done by Serge Dubovitsky, Jerry Mulder, and Duncan Liu of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Intellectual Assets Office
JPL
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4800 Oak Grove Drive
Pasadena, CA 91109
(818) 354-2240
E-mail: ipgroup@jpl.nasa.gov

Refer to NPO-30353, volume and number of this NASA Tech Briefs *issue, and the page number.*

Clamps for Testing Cable Shields and Connector Shells

Connector test clamps (CTCs) are clamping electrical connectors designed for use in testing electrical continuity from the backshell of a connector at one end of a shielded electrical cable, through the cable shield, to the backshell at the other end of the cable. CTCs increase the reliability of testing of shielded electrical cables beyond that achievable with alligator clips (for which suitable attachment points often cannot be found). Each CTC consists of a conductive jaw mounted onto a manually operated ratcheting clamp that can be released by finger pressure on a lever. CTCs can be made with jaws of various sizes and shapes to fit a variety of connector shells or applications. Each CTC is machined to allow connection of a standard banana-jack-tipped test lead. Once the CTC is clamped into place, one end of the test lead is inserted into the jaw and the other into any type of test equipment required. CTCs can be utilized in any application where a standard alligator clip is not sufficient.

This work was done by Kenneth A. Reaume of United Space Alliance for **Kennedy Space Center**. *For further information, please contact Phil Restivo, 1150 Gemini Ave., M/S: USH-100 D, Houston, TX 77058, Tel. No. (321) 212-6125, E-mail: Philip.G.Restivo@USAHQ.UnitedSpaceAlliance.com*

KSC-12286

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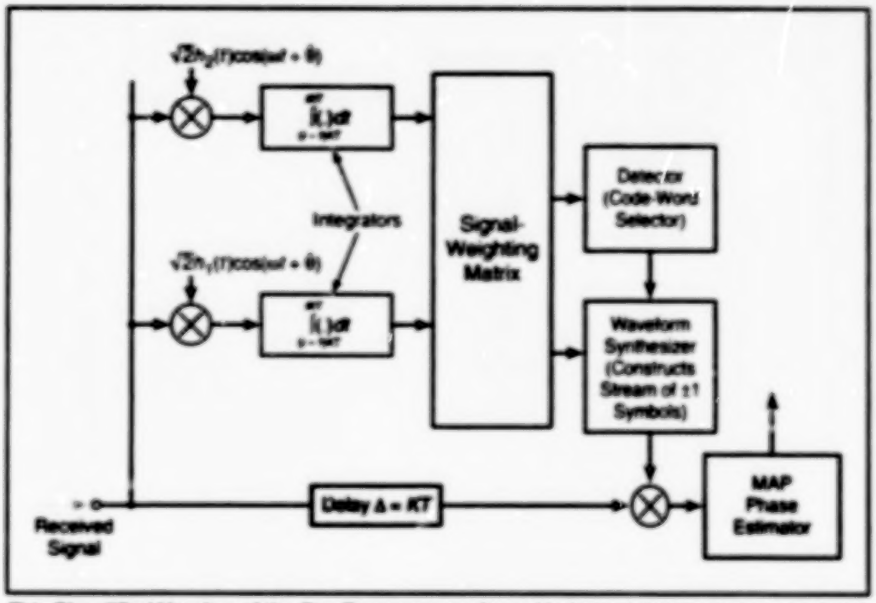
Generalized Pre-Processor for Block and Convolutional Codes

The design could be simplified by taking advantages of the structures of the codes.

NASA's Jet Propulsion Laboratory, Pasadena, California

A generalized data processor, proposed for use in the reception of binary-phase-shift-keyed (BPSK) radio signals, provides preliminary estimates of the block and convolutionally encoded symbols that are meant to be conveyed by the BPSK modulation. In a process denoted information-reduced maximum *a posteriori* (MAP) phase estimation, an estimate of the instantaneous symbol (and thus of the instantaneous phase modulation) is used to reduce the amount of randomness and information by converting the received modulated carrier to an approximation of an unmodulated carrier. The resulting partially reconstructed carrier is then fed as input to a MAP phase estimator to improve phase-tracking performance. The basic principles of information-reduced MAP phase estimation were described in somewhat more detail in "Information-Reduced Carrier Synchronization for Coded PSK Operation at Low-SNR" (NPO-20261), *NASA Tech Briefs*, October 1998.



This **Simplified Version of the Pre-Processor** performs Hadamard decomposition and signal reconstruction.

A detailed description of the generalized pre-processor can be found in the TMO Progress Report 42-144, October 2000, "Generalized Pre-Processor for Block and Convolutionally Coded Signals." Here we present a brief summary of the generalized pre-processor (see figure), which makes use of the algebraic structures of block and convolutional codes. In the coherent mode of operation, this pre-processor decomposes the received code words by use of orthogonal Hadamard basis functions and generates a vector of coefficients of length K (where K is the number of bits per code symbol) for each received block. Next, the coefficient vector is multiplied by a signal-weighting matrix to generate a vector of log-likelihood functions. The largest component of this decision vector is identified, and its index used to reconstruct the decoded code word.

The structure of the pre-processor remains essentially the same for any linear code of a given block length, except for the signal-weighting matrix, which is unique to each code. The signal-weighting matrix is pre-computed for each coding scheme by first generating the set of code words, then multiplying the Hadamard matrix by the coefficient matrix representing all possible code words.

The proposed generalized pre-processor was tested in computational simulations. The results showed that under representative conditions, including signal-to-noise ratios ranging from –5 to –10 dB, the increase in carrier-phase-estimation performance is equivalent to the improvement afforded by strengthening the received signal by 5 to 6 dB.

This work was done by Victor Vilnrotter, Clement Lee, and Norman Lay of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-30129, volume and number of this NASA Tech Briefs issue, and the page number.

Improved Transponder for Earth/Spacecraft Communication

This transponder utilizes advanced digital signal-processing techniques.

Lyndon B. Johnson Space Center, Houston, Texas

A prototype of a relatively inexpensive S-band transponder has been developed for use aboard a spacecraft as part of a NASA spacecraft tracking and data network (STDN). The transponder design incorporates recent advances in digital processing of received radio signals. Notable features of the design include flexibility in the choice of operating modes and "smart" acquisition of signals. The transponder design could also be adapted to military ground-based satellite communications and tracking and to commercial Earth/satellite communication systems.

The overall function of the transponder is to receive an S-band signal (uplink signal) from the ground, demodulate the signal to extract command and control information, and generate a return carrier signal modulated by either ranging or telemetry data to be transmitted back to the ground (downlink signal).

The STDN waveform comprises a binary-phase-shift-keyed (BPSK) subcarrier phase-modulated onto an S-band carrier. The transponder must phase-lock to the received uplink signal, determine frequen-

cy of the received carrier, and generate the return carrier signal at a frequency of exactly 240/221 times that of the received carrier signal.

The receiver portion of the transponder includes a flexible front end that enables selection of any of the STDN channels. An analog down-converter translates the S-band received signal to an intermediate frequency (IF) of ≈3 MHz in a noncoherent mode for in-phase and quadrature detection. An all-digital carrier-tracking loop coherently extracts the carrier from this IF signal. A field-programmable gate array is used to implement a carrier-tracking algorithm that supports operation of a first-, second-, or third-order phase-lock loop. The order of the loop can be changed by changing digital coefficients of a filter that is part of the loop. The return signal is translated from the IF to S band via a triple conversion process that maintains coherence between the received and transmitted carrier signals. An S-band linear phase modulator supports direct modulation of the return carrier signal.

Once the carrier has been extracted from the incoming signal, it is necessary to demodulate the subcarrier signal to extract the baseband signal that contains the command and control data; this involves subcarrier-lock and bit-synchronization operations that are performed by two commercially available application-specific integrated circuits that implement an all-digital early/late integrate-and-dump technique. The design of the transponder also incorporates an option to perform frame synchronization and Viterbi decoding. A commercially available digital signal processor performs frame-synchronization and system-control functions and serves as a communication interface with the host computer. Every system variable is editable via this transponder/computer interface.

One of the main features of the design is its ability to acquire the received carrier signal in the presence of modulation. This feature makes it unnecessary to perform a tedious acquisition exercise to lock the uplink and downlink prior to transmitting data. When, as sometimes happens, lock is lost, the transponder reacquires lock automatically. The transponder can also detect whether the carrier-tracking loop has locked to a sideband and, if so, can automatically correct the operation of the affected oscillators to cause the loop to lock on the desired uplink carrier signal.

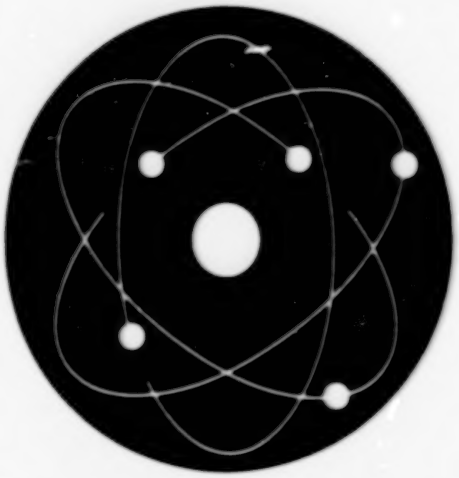
This work was done by David Sanderlin of Shason Microwave Corp. for **Johnson Space Center**. *Further information is contained in a TSP [see page 1].*
MSC-23074

Making Audible Alarms More Noticeable in Noisy Environments

An improved method of generating audible alarms has been invented for stressful environments in which there may be considerable background noise and where the intended recipients of the alarms also need to pay attention to sounds other than the alarms. An aircraft cockpit is a typical example of such an environment. This method does not rely on a sustained loud alarm to attract attention because a loud alarm can be gratuitously startling and can mask other sounds that also demand attention. Instead, this method comprises the following elements: (1) The initial alert and subsequent reminders are given via short bursts of synthesized stereophonic signals with a spectrum sufficiently distinct from the noise spectrum to be noticeable. (2) Using pairs of earphones or loudspeakers to implement the stereophony, the alarm signal is made to appear to rapidly alternate between arrival from two different directions. (3) The alarm signal can be supplemented via stereophonic manipulation of background-noise signals.

This work was done by Durand R. Begault of **Ames Research Center**.

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14556.



Physical Sciences

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Optical Fourier-Plane Analysis of Suspended Particles

This technique would be used to diagnose samples of blood cells and other biological materials.

Lyndon B. Johnson Space Center, Houston, Texas

Optical Fourier-plane analysis may prove useful for obtaining statistical data on the densities, sizes, shapes, indices of refraction, and perhaps other properties of particles (particularly, biological cells) suspended in liquids. This concept could potentially be the basis of a new class of simple, portable, relatively inexpensive instruments for diagnosis of samples of blood and other biological materials.

As currently envisioned, the concept involves placement of the sample of liquid/particle suspension in a specially designed transparent two-piece acrylic container. One of the pieces is said to be lenticular because its inner face features a linear array of grooves like the grooves of a diffraction grating or the Fresnel analog of a cylindrical lens (see Figure 1). The sizes and shapes of the grooves may or may not change incrementally along the array, depending on the specific application. Typically, the lineal density of channels is 100 to 200 per inch (about 40 to 80 per centimeter).

The other piece of the container includes a flat plate that covers the grooves, leaving the ends of the grooves open. This other piece can also include a handle for holding the container and an area for placing a drop of the liquid/particle suspension to be analyzed. Once placed, the liquid moves to and fills the grooves by capillary action.

The filled container is positioned in the apparatus shown in Figure 2, at the focal point of the Fourier-transform lens. The container is illuminated with light from the laser. The intensity in the resulting Fourier-transform image is measured as a function of position along an axis perpendicular to the grooves. This measurement is performed by use of a photodetector with a slit aperture in the Fourier-transform plane; the photodetector is moved along this axis by use of a translation stage. The relative intensity measured as a function of position constitutes a Fourier signature that can be analyzed to determine the relative concentrations of particles (cells) of various sizes.

The feasibility of this concept was demonstrated in preliminary experiments on suspensions of microspheres with diameters of 2, 4.5, and 15 μm. The best results were obtained with a lenticular piece featuring a prismatic groove pattern — the sawtooth pattern shown in Figure 1. Each suspension was found to produce a unique and repeatable Fourier-transform signature. Similar results were obtained in preliminary experiments on samples of blood.

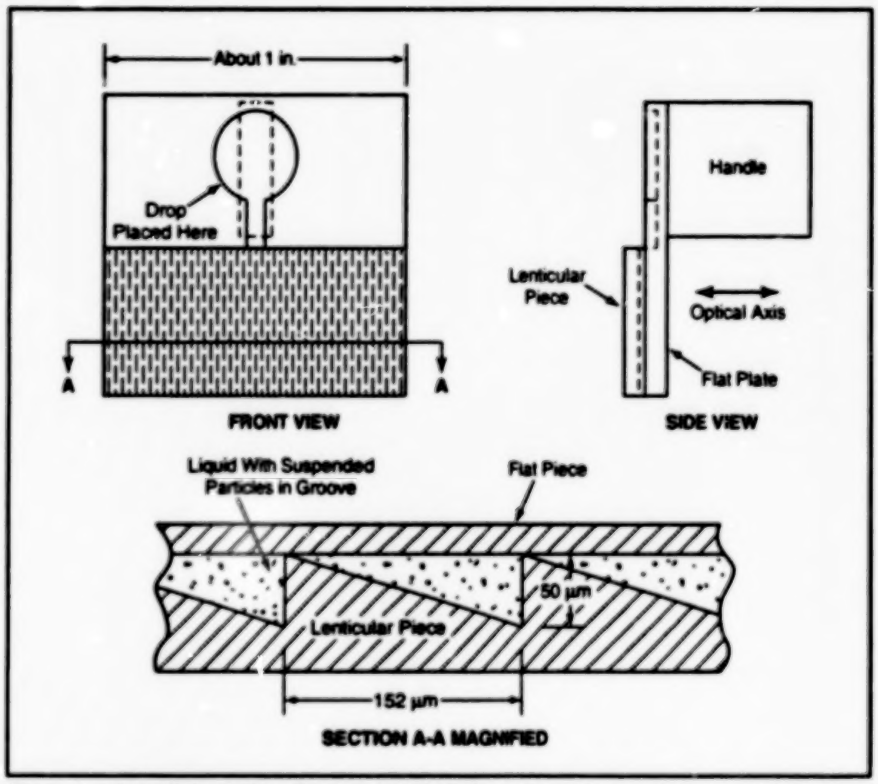

Figure 1. A Liquid Containing Suspended Particles is placed in a container, one of the inner faces of which is grooved.

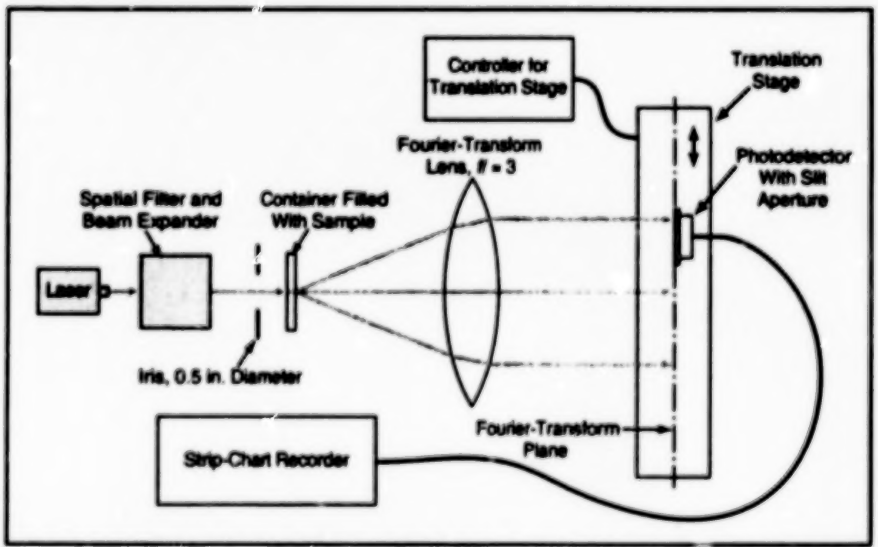

Figure 2. The Fourier-Transform Image of a filled container like that of Figure 1 is scanned to obtain statistical data on the suspended particles.

This work was done by Steven H. Mersch of Point Source, Inc., for **Johnson Space Center**. *Further information is contained in a TSP [see page 1].*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

Mr. Steven Mersch
Point Source
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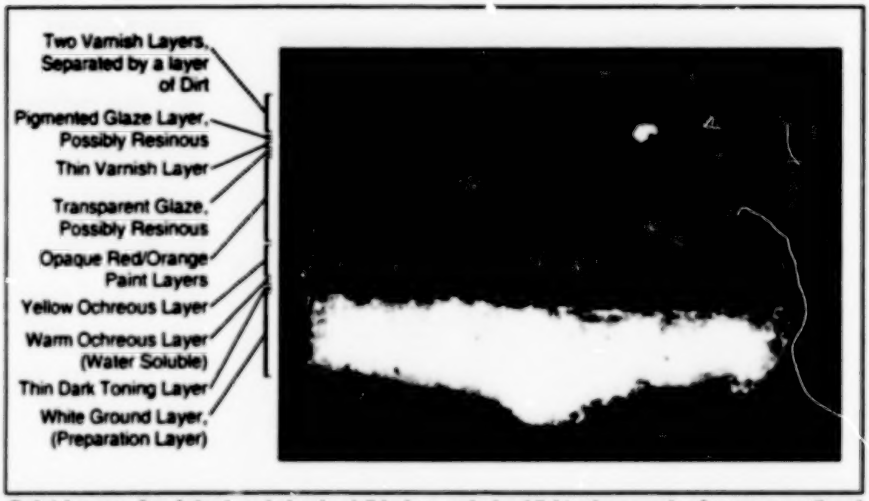
Germantown, OH 45327
Telephone No: (513) 855-6020

Refer to MSC-22575, volume and number of this NASA Tech Briefs *issue, and the page number.*

Preparing High-Quality Micrographic Samples of Oil Paintings

Cross-sectional specimens are prepared with wet grinding followed by dry polishing.

John H. Glenn Research Center, Cleveland, Ohio



Paint Layers Are Intact and clearly visible in a polarized-light micrograph of a cross-sectional specimen taken from an oil panting.

A technique similar to that of metallography has been devised for preparing cross-sectional micrographic specimens from small samples cut from oil paintings. Art experts at the Cleveland Museum of Art use the technique in their efforts to determine painters' methods and to verify the authenticity of paintings. By implementing the technique with automated polishing equipment, they can prepare a cross-sectional specimen in 20 min, and a publication-quality photomicrograph (see figure) can be made from the specimen. In contrast, the prior manual preparation technique took about 4 h and yielded specimens that contained scratches and were not flat enough for viewing at higher magnifications.

The technique is applied to a small (< 0.2 mm) sample that is removed from the painting with a scalpel. The sample is cast in polyester resin in a standard metallographic mount. The mount is then ground and polished in two stages to expose the desired cross section. The first stage involves traditional grinding with silicon carbide abrasive papers in water lubricant at a normal force of 200 N; a succession of four ever finer papers is used, starting with 320 grit and ending with 2,400 grit. The grinding time at each of the first three grits is automatically limited to 30 s. The grinding at 2,400 grit is stopped when the ground surface is within 10 μm of the sample, as measured by bright-field and polarized-light microscopy.

The second, more delicate, stage involves dry polishing; that is, dry grinding with a succession of even finer grits. First, silicon carbide in six steps of 1,500 through 6,000 grit is used, followed by aluminum oxide of 8,000, then 12,000 grit. Dry grinding must be used in exposing the cross section of the sample because some layers of the paint may be soluble in water, ethanol, kerosene, and other traditional grinding and polishing lubricants. A normal force of 10 N is applied in this stage. The grinding times are 10 s for each of the first three SiC grits, 15 s for each of the second three SiC grits, and 20 s for each of the Al_2O_3 grits. The resulting surface is highly polished and suitable for photomicrography.

This work was done by Todd Leonhardt of NYMA, Marcia Steele of the Cleveland Museum of Art, and William Waters of Waters and Associates for **Glenn Research Center**. *Further information is contained in a TSP [see page 1].*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Glenn Research Center [see page 1]. Refer to LEW-16177.

Pyrolytic-Graphite Gauges for Measuring Large Heat Fluxes

These gauges exploit the high-temperature endurance and thermal-conduction anisotropy of pyrolytic graphite.

Marshall Space Flight Center, Alabama

Gauges made of slugs of pyrolytic graphite with thermocouples embedded in them have been invented for use in measuring large, short-duration heat fluxes in hot, highly corrosive environments. These gauges were originally intended for use in combustion chambers of rocket engines; they might also be useful in terrestrial combustion chambers (e.g., in furnaces) and metal-processing equipment.

A gauge of this type is basically a calorimeter with a thermal mass large enough that its thermal-transient-decay time is significantly greater than the duration of the heat flux that one seeks to measure. One surface of the slug is placed in contact with the surface across which one seeks to measure the heat-flux density; the opposite surface of the slug is kept insulated. Then given the mass and specific heat of the slug and assuming that the slug is approximately isothermal at any given instant, the net flux of heat into the slug can be estimated as the product of the mass of the slug, the specific heat of the slug, and the rate of change of temperature as measured by the thermocouple in the slug. Then given the area through which heat flows into or out of the slug on the surface of interest, the heat-flux density is given simply by the estimated flux divided by this area.

As described thus far, the slug could be made of any of a variety of thermally conductive materials. The reasons (other than high-temperature endurance and resistance to corrosion) for making the slug out of pyrolytic graphite are best explained by the example of the figure. Pyrolytic graphite exhibits anisotropic thermal conductivity: its conductivity is high (comparable to that of copper) in two perpendicular directions and low (about 10^{-2}x as much) in the third perpendicular direction. In this case, the material in the slug is oriented so that the high conductivity is along the *H* and *L* axes and the low conductivity along the *W* axis. The high conductivity along the *H* and *L* axes helps to keep thermal gradients within the slug small, thereby making the response of the thermocouple fairly insensitive to its depth within the slug and justifying the assumption of isothermality. The low thermal conductivity along the *W* axis makes it possible to fabricate the slug as a plate that

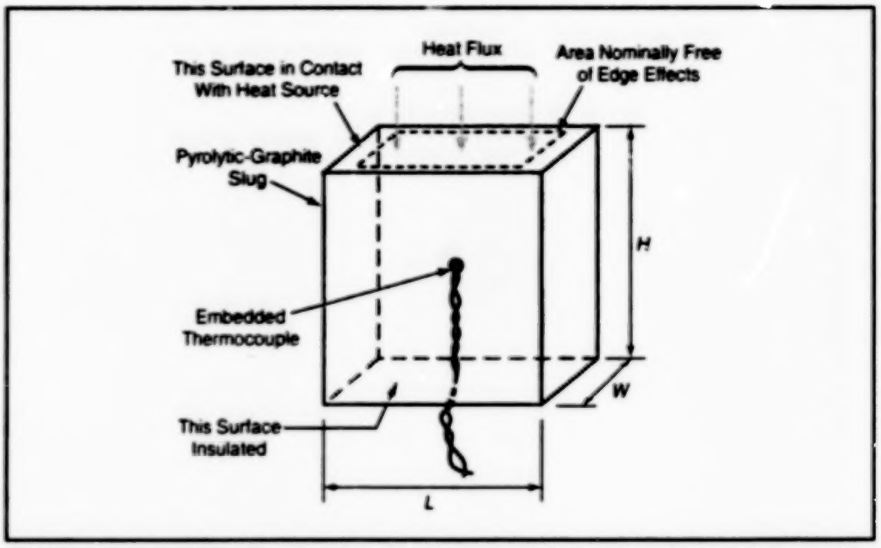
is thin along the *W* axis while still avoiding thermal gradients that would otherwise be caused by edge effects.

This work was done by Robert C. Bunker, Mark E. Ewing, and John L. Shipley of Cordant Technologies for **Marshall Space Flight Center**.

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)] to Thiokol Propulsion. Inquiries concerning licenses for its commercial development should be addressed to

Thiokol Propulsion
P.O. Box 707
M/S A11
Brigham City, UT 84302-0707

Refer to MFS-31572, volume and number of this NASA Tech Briefs issue, and the page number.



This Slug-Type Heat-Flux Gauge exploits the anisotropic thermal conductivity of pyrolytic graphite. Here, the high-conductivity dimensions are *H* and *L*, and the low-conductivity dimension is *W*.

Wind and Mountain Wave Observations From a Flight Test of a Solar-Powered Airplane

This airplane was shown to be useful for observing atmospheric waves.

Dryden Flight Research Center, Edwards, California

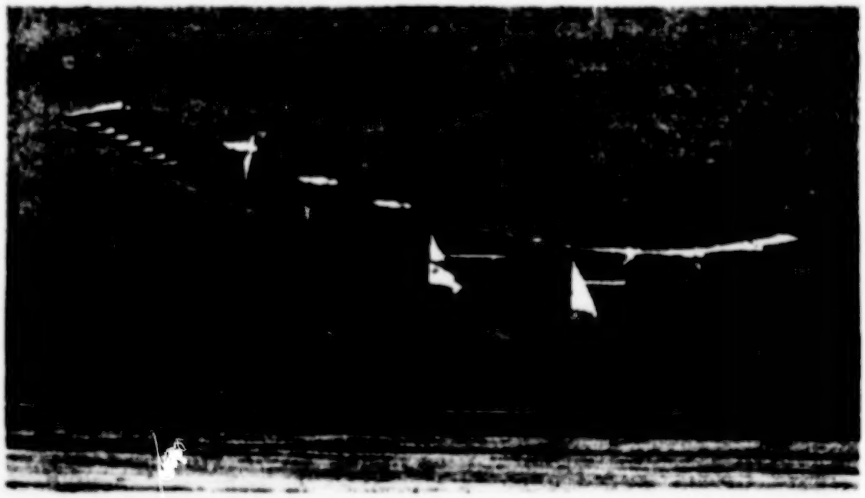


Figure 1. The Pathfinder Solar-Powered Airplane is shown here taking off for its record-breaking flight on June 9, 1997.

In support of NASA's Environmental Research Aircraft and Sensor Technology (ERAST) program, flight tests of the Pathfinder solar-electric-powered, remotely piloted aircraft (RPA) were conducted at the Navy's Pacific Missile Range Facility (PMRF), Barking Sands, Kaua'i, Hawaii, from May to November 1997 and from June to August 1998. This airplane was designed to operate at low speeds and low Reynolds numbers for long duration at altitudes above 60,000 ft (18 km). Three successive altitude world records for propeller-driven aircraft were established during these tests: 67,400 ft (20.54 km) on June 9, 1997; 71,350 ft (21.75 km) on July 7, 1997; and 80,201 ft (24.445 km) on August 6, 1998.

The 1997 Pathfinder airplane was of a flying-wing configuration (see Figure 1) with a span of 99 ft (30 m) and a chord of 8 ft (2.4 m). With a nominal gross weight of 500 lb (mass of 227 kg), the wing loading was extremely light — less than 0.64 lb/ft^2 (30.6 Pa). The airplane was propelled by 6 electric motors powered by a solar-cell array on the upper surface during the day and by batteries at night. The airplane had an equivalent airspeed of 17 knots (8.7 m/s) with an overall climb and descent rate of nominally 220 ft/min (1.1 m/s). The airplane was designed to carry a payload of as much as 50 lb (23 kg) to high altitude for studies of the atmosphere and ecosystem and for development of sensors.

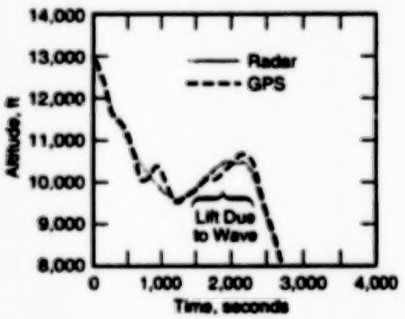


Figure 2. The Altitude History of the portion of the flight that included the encounter with the wave was reconstructed from radar and GPS readings.

The extremely light wing loading made the airplane highly responsive to gusts and highly sensitive to winds during takeoff and landing as well as during pre- and post-flight ground handling. Wind speeds aloft that exceed the true airspeed of the airplane could be expected to make it difficult to navigate to desired and approved regions of airspace.

During descent from the record altitude on June 9, 1997, the airplane encountered a mountain-wave updraft near an altitude of 9,600 ft (2.9 km) approximately 3 nmi (5.6 km) west of the Kaua'i coastline. The remainder of this article describes the observations made in connection with this encounter. A brief description of the local geography is prerequisite to a meaningful report of the observations: PMRF is situated on the west side of the island of Kaua'i. The 5,200-ft (1.6-km) Mt. Waialeale and a north/south mountain ridge line divide the island in half 16 mi (26 km) to the east. The mountain and ridge line block and divert the easterly trade winds. Lihue lies to east of the Mountain and ridge line.

Early on June 9, 1997, weather conditions were considered acceptable for a Pathfinder flight: At 06:00 Hawaii standard time (HST), surface winds at PMRF were light and variable — perfect for rolling the airplane out and preparing it for takeoff. All upper-level winds were below aircraft true-airspeed limits as measured by the PMRF 02:05 HST and 04:38 HST rawinsonde balloons. The National Weather Service (NWS) had forecast that during the next 24 hours, upper-level winds would decrease slightly while "trade" winds at Lihue would increase slightly. Surface winds at PMRF were expected to increase to 10 knots (5 m/s) by noon and then slowly decrease to light and variable by 19:00 HST.

The airplane first encountered the updraft at 21:15 HST. The conditions near encounter time indicated a very stable temperature profile, winds at the top of the ridge [altitude > 5,000 ft (>1.5 km)] near 15 knots (8 m/s), and wind direction perpendicular to the ridge line. Measurements of these winds came from three sources: airplane onboard instrumentation [true-airspeed indicator and a Global Positioning System (GPS) receiver], a NWS balloon released from Lihue at 02:00 HST on June 10, and PMRF balloons released at 19:14 HST on June 9 and 05:38 HST on June 10.

Data from the GPS receiver and from a ground-based radar tracking system were used to reconstruct the horizontal and vertical components of the position and velocity of the airplane. During the 15 minutes following the initial encounter, the wave slowly lifted the airplane 900 ft (274 m) at a rate of 60 ft/min (0.3 m/s), as shown in Figure 2. While in the wave updraft, the airplane maintained this rate of climb. After leaving the wave, the airplane descended at a rate of 300 ft/min (1.5 m/s), which likely included the effect of a downdraft. Thus, the overall variation in the rate of climb was 360 ft/min (1.8 m/s) — twice as great as indicated by the balloon closest to the encounter time, but considerably less than that indicated by the last balloon above an altitude of 14,000 ft (4.3 km).

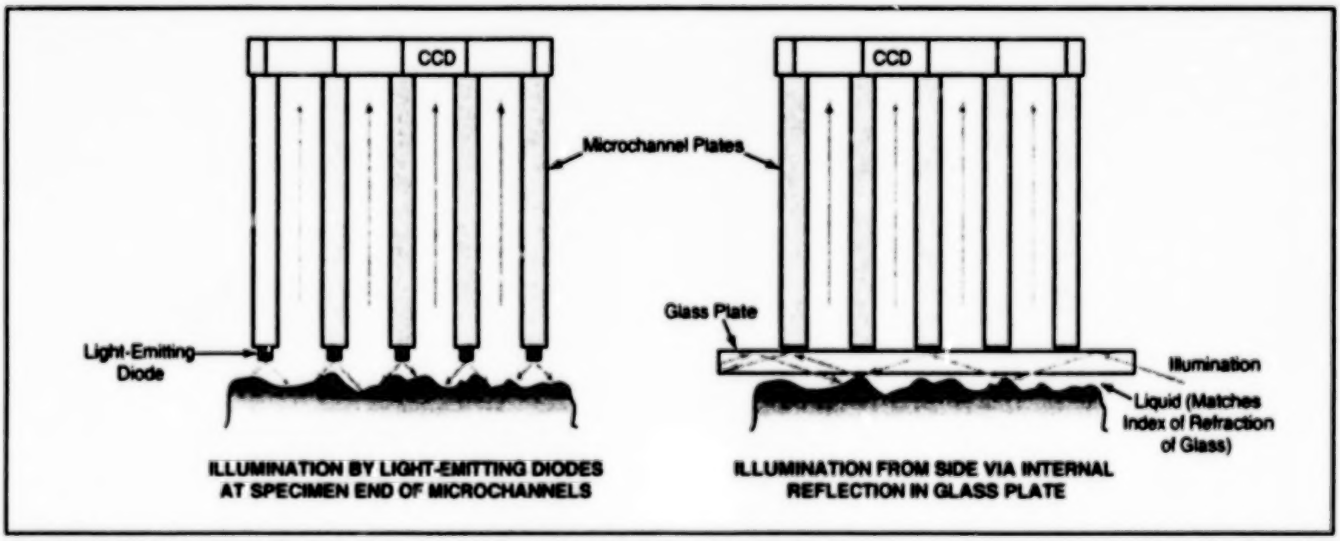
These observations indicate that the climb and descent performance of the Pathfinder airplane is a sensitive observation tool for the study of weak or light wave activity. Conversely, the sensitivity of Pathfinder to weak wave motion indicates the value of closely monitoring the meteorological profile for conditions that favor the development of waves and the importance of extracting the rates of rise of balloons from rawinsonde releases. On subsequent Pathfinder flights, balloon rise rates were monitored and analyzed for indications of up- and downdrafts. Advising flight planners and mission managers of the possibility of encountering waves enables them to account for anomalous climb- and descent-rate behavior. In addition, it makes them better prepared to navigate successfully through such phenomena to obtain additional flight time that may be needed prior to landing.

This work was done by Edward H. Teets, Jr., of Analytical Services and Materials, Inc., and Natalie Salazar of New Mexico University for **Dryden Flight Research Center**. *Further information is contained in a TSP [see page 1].*
DRC-98-82

Reflective Variants of Miniature Microscope Without Lenses

The specimen would be illuminated in reflection rather than in transmission.

NASA's Jet Propulsion Laboratory, Pasadena, California



This Miniature Microscope, like its predecessor described in the cited prior article, would not contain any lenses or other focusing optics. Focusing would not be necessary because the microchannels would effect a one-to-one mapping from locations on the specimen to pixel locations on the CCD.

The figure schematically depicts two proposed alternative versions of an instrument that amounts, in effect, to a compact, lightweight optoelectronic microscope that contains no lenses and generates a magnified video image of a specimen. The instrument was described in "Miniature Microscope Without Lenses" (NPO-20218), *NASA Tech Briefs*, August 1998. In the design and construction of the instrument, the focusing optics of a conventional microscope were replaced by a combination of a

microchannel filter and a charge-coupled-device (CCD) image detector. Elimination of focusing optics reduced the size and weight of the instrument and eliminated the need for the time-consuming focusing operation. At the time of the previous article, the instrument was only at the conceptual stage of development, but since that time, a prototype of the instrument has been built and demonstrated to function as intended.

The main differences between the previous version and the present proposed versions of the lensless microscope lie in the manner in which the specimen would be illuminated. The previous version was designed for a partly transparent but highly scattering specimen. The specimen was illuminated in a transmission mode with highly collimated light that was aimed through the specimen parallel to the axes of the microchannels.

According to the present proposal, the specimen would be illuminated in either of two reflection modes. In one case, the illumination would be provided by microscopic light-emitting diodes mounted on the walls between the microchannels, facing the specimen. In the other case, the specimen would be covered by a glass plate. Illumination would be brought in from the side by total internal reflection in the glass plate. A fluid with an index of refraction equal to that of the glass would be placed between the specimen and the glass plate to couple the illumination onto the specimen. There would be a thin airgap between the glass plate and the microchannel plate. Some of the light scattered and reflected by the specimen would travel along the microchannels to the CCD, as in the other versions of this instrument.

This work was done by Yu Wang of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
NPO-20610

Spectral Region for Laser Isotope Measurements of Gases

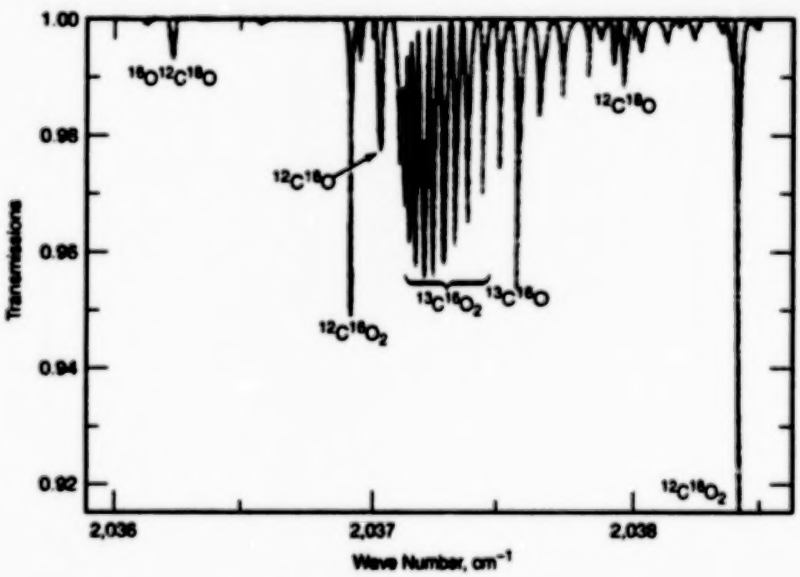
Tunable-laser absorption measurements yield temperature and concentrations of six isotopic species.

NASA's Jet Propulsion Laboratory, Pasadena, California

A mid-infrared wave-number range has been identified as being useful for laser measurements of CO and CO_2 gases that contain various combinations of isotopes of C and O. The isotopic species are $^{12}C^{16}O$ (common CO), $^{13}C^{16}O$, $^{12}C^{18}O$, $^{16}O^{12}C^{18}O$, $^{12}C^{16}O_2$ (common CO_2), and $^{13}C^{16}O_2$.

More specifically, the wave-number range from about 2,036.2 to 2,038.4 cm^{-1} (wavelength range from about 4.9111 to about 4.9058 μm) contains two absorption spectral lines for $^{12}C^{16}O_2$, a group of lines for $^{13}C^{16}O_2$, and one line for each of the other isotopic species (see figure). The range is narrow enough that it can be spanned by a typical tunable laser.

From measurements of the absorption of laser light in this wavelength range, one can determine simultaneously the temperature of a gas mixture and the concentration of each of the six isotopic species. Potential applications for instruments based on this measurement principle include Earth and planetary gas spectrometers; analysis of exhaled, isotope-tagged CO and CO_2 for medical diagnosis; analysis of isotope-tagged CO and CO_2 for research on the operation of automotive engines and the resulting pollution; and other applications in industries that involve the sensing and/or measurement of gases.



The Transmission Spectrum of a mixture of isotopic species of CO and CO_2 contains distinct absorption lines for each of the species in narrow wave-number range centered at about 2,037 cm^{-1}. The $^{13}C^{16}O_2$ Q-branch lines would provide an independent determination of temperature. The spectral simulation shown is typical for Mars atmospheric conditions.

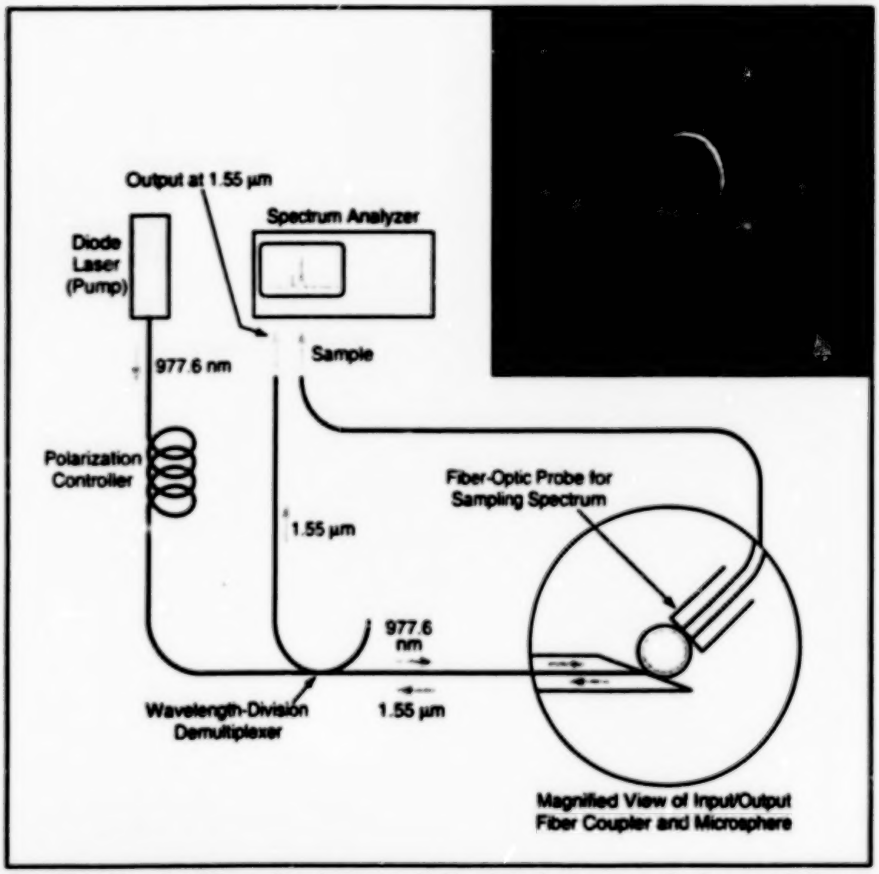
This work was done by Christopher Webster of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
NPO-21163

Fiber-Coupled Microsphere Laser at Wavelength of 1.55 μm

Coherent radiation can be generated or amplified by an extremely compact device.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure depicts the laboratory setup of an optical-fiber-coupled microsphere laser with an output in the 1.55-μm wavelength band used in some communication systems. This laser offers the obvious advantages of compactness and simplicity. In addition, as consequences of the high resonance quality factor (Q) and smallness of the microsphere, it also offers the non-obvious advantages of a high degree of spectral purity and a low threshold power level. This laser could be useful as a source of highly coherent infrared light or, if operated in a subthreshold regime, as a low-noise front-end amplifier in optical communica-



This Fiber-Coupled Microsphere Laser is a highly miniaturized source of coherent radiation at a wavelength of 1.55 μm. In the photograph, the lasing region is rendered visible by up-conversion-pumped fluorescence at wavelengths of 525 and 545 nm.

tion. Alternatively, with the addition of active mode locking, this laser could be the core of an ultra-compact optoelectronic oscillator that would generate a light signal modulated by a microwave signal according to the principle described in "Closed-Loop Microsphere Laser for Optoelectronic Oscillator" (NPO-20597), *NASA Tech Briefs*, September 2001.

The microsphere serves as both the resonator and the gain medium of the laser. It is made of a standard erbium-doped aluminosilicate glass ordinarily used as the core material of communication-band fiber-optic amplifiers. The pump light, at a wavelength of 977.6 nm, is generated by a diode laser. The pump light is supplied to the microsphere through a single angle-polished fiber-optic evanescent-wave coupler like the one described in "Simple Fiber-Optic Coupling for Microsphere Resonators" (NPO-20619), *NASA Tech Briefs*, May 2001.

Inside the microsphere, the pump light excites "whispering-gallery" waveguide modes that circulate by virtue of total internal reflection. In a standard erbium-doped-fiber laser or amplifier, the length of the active fiber must be at least a few meters to obtain enough absorption of the pump light. In the microsphere laser, the circulation of the "whispering-gallery" modes provides the necessary path length for absorption, thus making it possible to reduce the laser volume drastically. The 1.55-μm laser radiation is coupled back into the optical fiber and selected for output by a wavelength-division demultiplexer.

This work was done by Vladimir Ilchenko, Steve Yao, and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP [see page 1].*

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Refer to NPO-20918, volume and number of this NASA Tech Briefs *issue, and the page number.*

Electrostatic Systems Keep Dust Off Surfaces

These lightweight systems operate unattended and contain no moving parts.

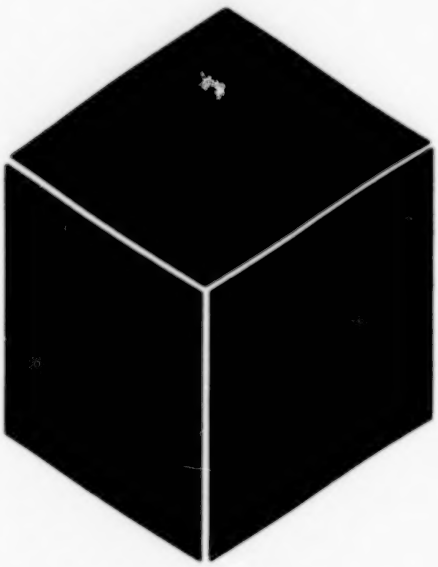
NASA's Jet Propulsion Laboratory, Pasadena, California

Electrostatic dust-collection systems that comprise wire grids connected to lightweight, low-power high-voltage sources have been invented for preventing the accumulation of dust on surfaces. Intended originally for use in keeping spacecraft solar panels free of dust, these systems could also be used on Earth to keep dust off such critical surfaces as those of semiconductor surfaces that await processing, highly sensitive optical instruments, and optoelectronic devices.

The wire grid in a system of this type is strung over the surface to be kept clean, then charged to a high potential to remove any dust from the surface by electrostatic attraction. Unlike prior systems developed to keep surfaces free of dust, systems of this type both contain no moving parts and can operate unattended.

This work was done by Brian Wilcox, R. Scott Cozy, and Mike Newell of Caltech for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP [see page 1].*

NPO-20788



Materials

Hardware, Techniques, and Processes

Books and Reports

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Fabricating Better PSSA-PVDF-Based MEAs for Fuel Cells

Changes in the fabrication process enhance electrochemical performance.

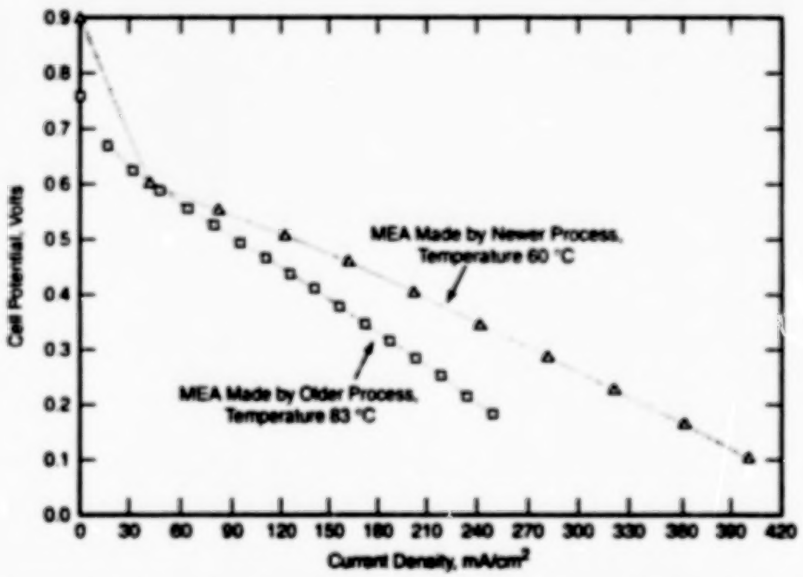
NASA's Jet Propulsion Laboratory, Pasadena, California

Some changes have been made in the fabrication of PSSA/PVDF-based membrane/electrode assemblies for direct methanol fuel cells. The effect of the changes is to improve the electrochemical performances of the cells.

Some rather detailed background information is prerequisite to a meaningful description of the changes. Each fuel cell contains a membrane/electrode assembly (MEA), which is a composite of a solid-electrolyte membrane sandwiched between catalyzed electrode layers. PSSA/PVDF is a composite material that has been recently found to be useful for making solid electrolyte membranes, as reported in "PSSA/PVDF Polymer Electrolyte Membranes for CH_3OH Fuel Cells" (NPO-20378), *NASA Tech Briefs*, June 1999. To recapitulate: a PSSA/PVDF membrane consists of cross-linked polystyrene sulfonic acid (PSSA) immobilized within an electrochemically inert matrix of poly(vinylidene fluoride).

Heretofore, the fabrication of an MEA has typically involved the following process: An ink for each electrode is prepared from a combination of (a) an electrocatalyst (Pt for the cathode, Pt/Ru for the anode) and (b) a solution of a perfluoro-sulfonated ion-exchange polymer dispersed in lower alcohols. Each ink is applied to either (a) a sheet of poly(tetrafluoroethylene)-impregnated porous carbon paper or (b) a surface of a solid-electrolyte membrane. The membrane is sandwiched between the carbon papers, which are destined to become the electrodes. The sandwich, in a hydrated condition, is then pressed at a temperature of 145 to 150 °C and a pressure of 2 kpsi (14 MPa).

Prior to the development of PSSA/PVDF membranes, the membranes in the MEAs of the most advanced direct methanol fuel cells were made from perfluoro-sulfonated ion-exchange polymers. The principal advantage of PSSA/PVDF membranes over membranes made from those and other polymer electrolyte materials is that the PSSA/PVDF membranes are less permeable by methanol; this translates to less methanol crossover and thus greater fuel-utilization efficiency. Relative to MEAs made from perfluoro-sulfonated ion-exchange membranes, MEAs made from PSSA/PVDF membranes exhibit comparable proton conductivity and less methanol crossover. However, until now, the electrical performances of the PSSA/PVDF-based MEAs have not been adequate for use in fuel cells. The inadequacy (in particular, high electrical resistance and poor utilization of catalyst) has been attributed primarily to poor interfacial bonding of the electrocatalytic layers with the proton-conducting moieties of the membrane. This completes the background information.



Two Methanol Fuel Cells were tested with a 1.0 M solution of methanol and oxygen at 20 psig (gauge pressure of 0.14 MPa), but at different temperatures. Even at its lower test temperature, the cell containing the MEA made by the newer process performed better.

The changes in the fabrication process are intended to improve the interfacial bonding and the formation of proton-conducting channels at the membrane/electrocatalyst interfaces. One of the changes is the addition of PVDF powder to the ink. The PVDF improves the interfacial bonding by making the ink more chemically and thermodynamically similar to, and thus more miscible with, the membrane. In addition, PVDF has low intrinsic permeability by methanol and thus helps suppress methanol crossover through the electrodes.

Another change is roughening the membrane prior to application of the catalytic electrode layers. Roughening enhances bonding by providing additional sites for anchoring the catalytic and polymeric electrode materials.

A third change is the addition of water and N,N-dimethylacetamide to the ink (which, in this case, is painted directly onto the membrane). These additions enhance bonding by increasing the plasticity of the membrane during hot pressing. These additions also enhance bonding by preventing undesired dryout during hot pressing.

In an experiment, the electrical performance of a fuel cell containing an MEA made by a process that incorporates these changes was measured, along with that of a fuel cell containing an MEA made by an older process. The cell containing MEA made by the newer process was operated at a lower temperature, yet it exhibited better performance (see figure). Inasmuch as the performance of a given cell increases with temperature, the performance of the MEA made by the newer process could be expected to exceed that of the other MEA by an even greater margin if both were tested at the same temperature.

This work was done by Sekharipuram Narayanan and Marshall Smart of Caltech and Tony Attl, Surya Prakash, and George Olah of the University of Southern California for **NASA's Jet Propulsion Laboratory.** *Further information is contained in a TSP* *[see page 1].*

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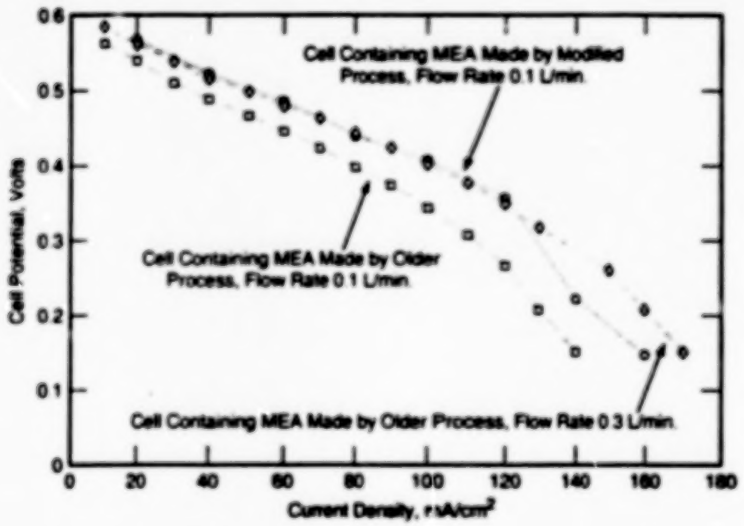
Making Hydrophobic Cathodes for MEAs in Fuel Cells

Poly(tetrafluoroethylene) powder is added to catalytic inks used to make electrodes.

NASA's Jet Propulsion Laboratory, Pasadena, California



Two Methanol Fuel Cells were tested at a temperature of 50 °C with a 1.0 M solution of methanol and flowing air. The electrode area is 25 cm², and the membrane used was Nafion 117 or equivalent.

The fabrication of membrane/electrode assemblies (MEAs) for direct methanol fuel cells can be modified to make the cathodes hydrophobic. These modifications improve the performances of the fuel cells, as explained below.

As in the preceding article, it is necessary to present some background information in order to give meaning to a description of the modifications. During operation of a direct methanol fuel cell, water is produced at the cathode. If not removed, the water blocks access of air to catalyst sites on the cathode, and the cell output voltage is consequently decreased. At a high rate (a large multiple of the stoichiometric rate) of flow of air or oxygen past the cathode, the blockage is less severe because the excess flow evaporates the water. However, the equipment needed to pump the air and condense the evaporated water adds to the size and weight of the fuel-cell system and consumes a significant amount of power, thereby decreasing the efficiency of the fuel-cell system.

The size and weight of the system could be reduced and/or the efficiency of the system could be increased if it were not necessary to rely on evaporation to remove the water from the cathode and thus the system could be operated at a lower airflow rate. To reduce or eliminate reliance on evaporation, it would be desirable to exclude the water (or at least some of the water) from the cathode in the first place by rendering the cathode at least partly hydrophobic. The essence of the present modifications of the fabrication process is to implement this concept by adding a hydrophobic constituent to the cathode material.

The hydrophobic constituent in question is a poly(tetrafluoroethylene) powder with a particle size ranging from 1 to 4 μm. The powder is added to the catalytic inks used to make the electrodes. Each ink is applied to both (a) a sheet of poly(tetrafluoroethylene)-impregnated porous carbon paper and (b) a surface of a perfluoro-sulfonated ion-exchange membrane that has been roughened by use of abrasive paper to increase adhesion. Then as in the process described in the preceding article, the membrane is sandwiched between the carbon papers and the sandwich is consolidated by applying heat and pressure.

In an experiment, the electrical performance of a fuel cell containing an MEA made by the modified process was tested, along with that of a fuel cell containing an MEA made by an older process. The cell containing the MEA made by the modified process performed nearly equivalently to other cell at a third of the flow rate, and performed better at the same flow rate (see figure).

This work was done by Sekharipuram Narayanan and Thomas Valdez of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

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Improved Polymer/Solid-Electrolyte Membranes for Fuel Cells

Because water would be unnecessary for proton conductivity, operating temperatures could be increased.

NASA's Jet Propulsion Laboratory, Pasadena, California

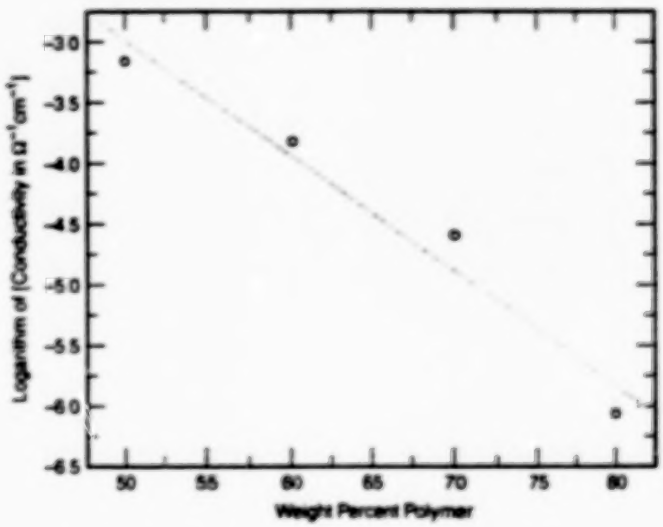
A class of developmental membrane electrolyte materials for methanol/air and hydrogen/air fuel cells is exemplified by a composite of (1) a melt-processable polymer [in particular, poly(vinylidene fluoride) (PVDF)] and (2) a solid proton conductor (in particular, cesium hydrogen sulfate). In comparison with previously tested membrane electrolyte materials, including those described in the two preceding articles, these developmental materials offer potential advantages of improved performance, lower cost, and greater amenability to manufacturing of fuel cells.

A principal limitation on the utility of the previously tested membrane electrolyte materials is that they must be hydrated to be able to conduct protons. This requirement translates to a maximum allowable operating temperature of about 90 °C, and the presence of water in the polymer

matrices undesirably gives rise to high permeability by methanol. It would be desirable to reduce permeability by methanol to increase cell performance and fuel-utilization efficiency, and it would be desirable to operate fuel cells at temperatures as high as 140 °C to increase their tolerance to carbon monoxide from reformate streams. Therefore, what are needed are membrane materials that conduct protons in the absence of water.

In a composite material of the type undergoing development, the polymer serves as a matrix to support the solid proton conductor. In cesium hydrogen sulfate, proton conduction occurs by a mechanism that does not depend on water. At room temperature, the protons are in a bound state and so there is little or no proton conduction. However, as the temperature rises past 130 °C and toward a value between 135 and 145 °C, the cesium hydrogen sulfate undergoes a phase transition to a state in which the hydrogen ions have a significant amount of mobility; that is, the material becomes a proton conductor. The conductivity can be as high as 0.1 $\Omega^{-1}cm^{-1}$ — of the order of the conductivities of the previously tested membrane electrolyte materials.

Some experimental polymer/solid electrolyte membranes have been fabricated by mixing PVDF and cesium hydrogen sulfate powders and pressing the mixtures in a die at temperatures between 160 and 190 °C. Other experimental membranes were prepared by forming slurries of the powder mixtures in organic solvents, casting the slurries on a plate, allowing the slurries to dry, and then hot pressing the slurries. The figure shows the logarithms of electrical conductivities of these membranes as a function of composition. At the time of reporting the information for this article, it was anticipated that these membranes would be used to fabricate membrane/electrolyte assemblies for testing in fuel cells.



The Electrical Conductivities of polymer/solid electrolyte composites made of various proportions of the same polymer and solid electrolyte were measured by an ac-impedance method at a temperature of 130 °C.

This work was done by Sekharipuram Narayanan, Sossina Haile, Dane Boysen, and Calum Chisholm of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

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Nontoxic X-Ray-Absorbing Windows

Tantalum oxide/polymer composites are molded into light-transparent plates.

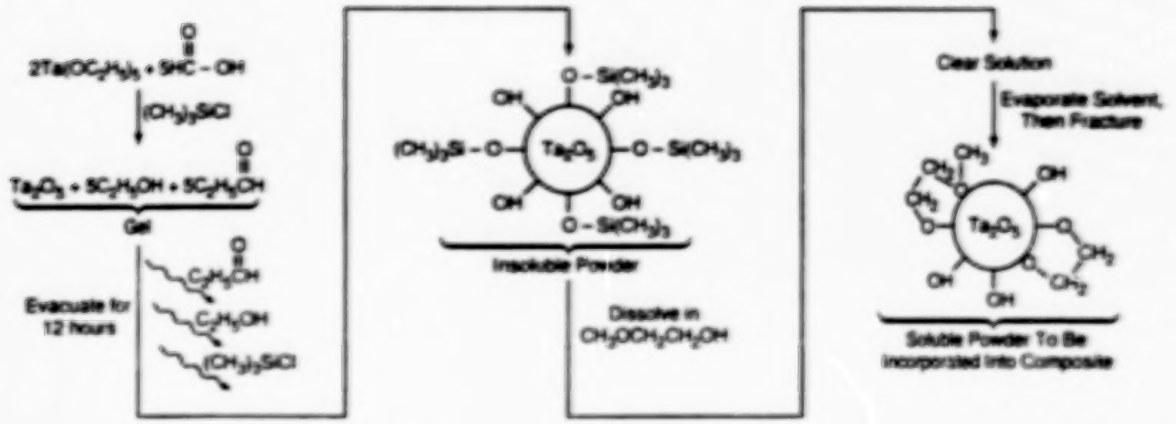
Lyndon B. Johnson Space Center, Houston, Texas

Windows that absorb x rays and are transparent to visible light can be made by compression molding of tantalum oxide/polymer composite materials. The main x-ray-absorbing medium in these windows is tantalum instead of lead, which is the traditional main x-ray-absorbing medium. These composite windows have been developed to replace lead-filled glass and lead-filled polymer x-ray-absorbing windows, which are unsuitable for use in some environments because of the toxicity of lead.

The composite materials are transparent to visible light because the tantalum oxide is contained in oligomeric clusters much smaller than the smallest wavelength of visible light. The first step in the synthesis of the clusters (see figure) is the formation of insoluble clusters of the general composition $Ta_xO_y[OSi(CH_3)_3]_z$ by hydrolyzing $Ta(OC_2H_5)_5$ with formic acid in the presence of $ClSi(CH_3)_3$. The clusters are then rendered soluble in alcohols by reacting them with a suitable alcohol such that the trimethyl siloxy group is replaced with an alkoxy moiety from the alcohol.

The resulting soluble oligomeric tantalum oxide clusters can be mixed in any proportion with methoxyethanol solutions of phenoxy (hydroxy aryl-alkyl ether) polymer to form a clear solution that can be cast into clear films. The films can be rendered brittle by cooling them in liquid nitrogen, then fractured while still brittle to produce a molding powder. Provided that the weight percentage of the tantalum oxide component of the powder is ≤80, the powder can be compression molded at a temperature of 150 °C to obtain a transparent plate. Alternatively, a film of the tantalum oxide/phenoxy composite can be cast on one of two sheets of polycarbonate of bisphenol A, then sandwiched between the two polycarbonate sheets under heat and pressure to obtain a laminated window with desirable mechanical and optical properties.

This work was done by Stephen T. Wellinghoff of Southwest Research Institute for **Johnson Space Center**. *Further information is contained in a TSP [see page 1].*



Oligomeric Clusters That Contain Ta_3O_5 are synthesized and made into an alcohol-soluble powder in this sequence of reactions.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to MSC-22401, volume and number of this NASA Tech Briefs issue, and the page number.

Books and Reports

Research on Life-Prediction Methods for MMCs — Phase I

A report describes the completed first phase of a NASA/industry cooperative program of research on metal-matrix composites (MMCs) as lightweight, strong, high-temperature-resistant materials for use in future aircraft engines. The first phase of the research included assessment of life- and fracture-prediction methods, determination of fracture strengths and fatigue lives, and experiments in nondestructive evaluation. The metal-matrix composite specimens used in these studies were rings made of silicon-carbide-based fibers in a titanium-alloy matrix. The particular composite material was chosen because extensive data on the material were already available and the material is representative of composites that would be used in aircraft engines. Five fracture- and life-prediction analysis methods were applied to the rings; their predictions were compared with each other and with experimental data on fracture of the rings. Manufacturing defects prevented the researchers from conducting planned cyclic tests. Fatigue-life predictions ranged from 1,000 to 15,000 cycles. Fracture-stress predictions were less scattered, ranging from 25 to 40.1 kpsi (172 to 276 MPa). Low-resolution x-ray computed tomography proved to be an effective nondestructive-evaluation technique.

This work was done by Erwin V. Zaretsky, John Gayda, Steven M. Arnold, George Y. Baaklini, Harold E. Kautz, Frederic A. Holland, Jr., Matthew E. Melis, Gary R. Halford, Christos C. Chamis, Pappu L. N. Murthy, Bradley A. Lerch, and Carol Vidoli of **Glenn Research Center**; *Michael G. Castelli and Surendra N. Singhal of NYMA, Inc; Robert E. deLaneuville, Phillip W. Gravett, and Larry D. Percival of United Technologies, Inc.; Robert N. Yancey of Advanced Research and Applications Corp.; and Thomas E. Wilt of the University of Toledo. To obtain a copy of the report, "MMC Life System Development (Phase I)—A NASA/Pratt & Whitney Life Prediction Cooperative Program," see TSPs [page 1].*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Tech Brief Patent Status, Mail Stop 7-3, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-16464.

Computer Programs

Mathematics and Information Sciences

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Mathematics and Information Sciences

GUI Software for Managing Router Configuration Files

Cisco IOS Manager (CIOSMAN) is a computer program that generates a graphical user interface for managing configuration files for an Internet-Protocol router. [In this context, "IOS" signifies the Cisco Internetworking Operating System and "router" signifies a system of computer-network switching hardware and software.] Heretofore, the management of configuration files has been difficult, time-consuming, and error-prone because (1) the files tend to be large and complex, especially when they contain large access control lists (ACLs); and (2) it has been necessary to update the files by manual text editing. CIOSMAN includes routines for analyzing master configuration files or a router configuration dump (to show a running configuration) and for manipulating of specific interfaces and ACLs via point-and-click selection. A multiform capability enables the user to navigate among forms without backing out of a previously chosen form. Changes in interface or ACL information are validated before they are applied to the affected database. There is an option for compiling and updating a file: this option provides all the commands needed to apply a change to an ACL on line via either an integrated or a separate Telnet application program.

This program was written by Wayne Edward Morse of United Space Alliance for **Kennedy Space Center**. *For further information, please contact:*

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KSC-12304

Software for Managing a Health and Environmental Database

Health and Environmental Resource System (HERS) is a relational-database computer program with a graphical user interface that assists members of an environmental health organization in the collection, analysis, and reporting of data pertaining to industrial hygiene, radiation health, environmental sanitation, control of pollution, management of construction, management of hazardous materials, and administration. Prior to the development of HERS, most of the data were stored, variously, in paper files or in non-relational computer files accessible by only one user. Consequently, there was no easy way to perform comprehensive assessments of risk, and reporting was jeopardized by inconsistency and unavailability of data. HERS is designed for a multiuser environment and provides for interactive management of data as well as robust tracking and scheduling of tasks. Web-based application programs to be linked with HERS are being developed to enable the exchange of data with customers and with employees in the field. Also under development is a capability for importing data from a geographical information system so that HERS data can be linked to map locations: All the data about a location shown on a map will be accessible by clicking on a mouse.

This program was written by Pamela Tucker and additional applications to enhance the program were also written by Chris Erickson, Kevin Garbin, and Gary Palmer, Jr., of Comprehensive Health Services for **Kennedy Space Center**. *For further information, please contact:*

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KSC-12248

Software Accelerates and Standardizes Procurement by NASA

Virtual Procurement Office (VPO) is a Web-based application program designed for use by procurement professionals throughout NASA. Prior to the development of VPO, each of the 700+ NASA procurement professionals had to spend much time searching numerous locations on-line and off-line for the various software tools and other resources necessary to complete each procurement task. VPO accelerates and standardizes the work of these professionals by giving them accurate and efficient means for gaining access to all relevant on-line resources that support the procurement process. The resources include (1) rules (e.g., Federal Acquisition Regulations); (2) samples (e.g., prior procurement documents that might be useful as guides); and (3) "build tools" — application software, forms, and document templates that should be used to complete procurement tasks. In order to provide a familiar interface, VPO was structured following the matrix format of NASA Form 1098, Checklist for Contract Award File Content. Each row on the matrix represents a possible step in the contracting process, e.g., market research or acquisition plan. For each row on the matrix, VPO provides a column with the capability to include "rules," "samples," "build tool," and "status."

This program was written by Jim Bradford, Dwight Clark, Steve Rowell, David Hieber, John Sudderth, and Laura Allen of **Marshall Space Flight Center**; *Gene Moses, Joanne Comstock, Deborah Glass, and Larry Reeve of Ames Research Center; Robert Greco of Dryden Flight Research Center; Wanda Behrens and Mary Ann Bishop of Goddard Space Flight Center; George Huff, Leigh Allen, and Kelly Mapham of Johnson Space Center; Sandy Gates and Donna Rafferty of Kennedy Space Center; Sandra Ray, Linda Urquhart, and Mary Deuell of Langley Research Center; Bruce Shuman of Glenn Research Center; Gay Irby and Jane Johnson of Stennis Space Center; and Michael Lalla of WSTF. Further information is contained in a TSP [see page 1].*

For further information, contact Caroline Wang, MSFC Software Release Authority, at (256) 544-3887 or caroline.k.wang@msfc.nasa.gov. Refer to MFS-31699.

Software for Scientific Exploration by Multiple Rovers

Multi-Rover Integrated Science Understanding System (MISUS) is a computer program designed to coordinate the activities of multiple small, instrumented robotic vehicles (rovers) engaged in autonomous scientific exploration of the surface of Mars. MISUS includes a component that utilizes machine-learning clustering methods to analyze scientific data (principally, image and spectral features of rocks) and, on the basis of analyses, to select new scientific activities. MISUS also includes a distributed-planning-and-scheduling component that determines the rover activities needed to achieve scientific goals, partly on the basis of initial rover conditions and an input set of goals. Plans

are updated on the basis of the results of the scientific analyses and current information on the execution of commands and utilization of resources. Planning is distributed among the individual rovers, each rover being responsible for planning its own activities. A central planning system is responsible for dividing up the goals among the individual rovers in a fashion that minimizes the total time of traversal of all rovers. The software as described thus far is also integrated with a simulation program that simulates multiple-rover scientific operations on Mars-like terrain.

This program was written by Tara Estlin, Alexander Gray, Darren Mutz, Ashley Davies, Eric Mjolsness, Gregg Rabideau, John Lou, Rebecca Castaño, Steve Chien, and Tobias Mann of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30201.

Methods and Software for Mining Data in Context

The Perilog methods and software provide a suite of data-mining tools. Perilog retrieves and organizes data from any sequence of terms that are contextually associated (e.g., text, music, genetic sequences). Perilog data mining includes: (1) keyterm-in-context search; (2) flexible, model-based phrase search; (3) model-based phrase generation; and (4) narrative-based phrase discovery. The methods and software measure the degree of contextual association for large numbers of paired terms to produce models that capture the structures of the sequences of terms. Perilog compares these models to a query model, develops a ranking, and presents the results of the search to the user. It can also extract phrases from the sequences. Perilog was originally designed to support the Aviation Safety Reporting System, which NASA operates for the Federal Aviation Administration. In that application it produced, from a database of tens of thousands of documents, the first quantitative evidence of situational relationships between reported commercial aviation incidents and a specific type of aviation accident. Perilog can be used to mine databases for any type of information.

The Perilog methods and software were created by Michael McGreevy of **Ames Research Center**. *This technology is available for commercial licensing. For further information, access http://ettc.usc.edu/ames/perilog/homepage.html.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14512/3/4/5.

Software for Capturing Software-Design Rationale

Better Elicitation and Communication of Arguments Underlying Software Engineering (BECAUSE) is a computer program that records and codifies the rationale that underlies decisions made in the course of developing software. To minimize the additional sensory, cognitive, and motor demands upon the computer programmer and the time needed for the rationale-capture task, BECAUSE elicits spoken commentary, from the programmer, in regard to the specific software design or source code on which the programmer is currently working. Therefore, a microphone and speech-digitizing circuitry are used and BECAUSE incorporates speech-recognition software that processes digitized speech signals. BECAUSE also incorporates subprograms that perform the following functions:

- *Elicitation* — asking questions of the programmer to stimulate commentary;
- *Correlation* — mapping the captured commentary to the design or code segments being edited during the commentary;
- *Abstraction* — mapping the commentary to explicitly or implicitly referenced higher-level entities, including issues, software objects, and design changes;
- *Navigation* — placing the commentary via hyperlinks within a stored network of issues, alternatives, and decisions; and
- *Presentation* — rendering the captured design record in a form understandable to the same or a different programmer.

This program was written by Sidney C. Bailin of Knowledge Evolution, Inc., for **Kennedy Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to KSC-12339, volume and number of this NASA Tech Briefs *issue, and the page number.*

Mechanics

Hardware, Techniques, and Processes

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Control Derivatives of the F-18 Airplane

These derivatives will be used in designing an active-aeroelastic-wing control system.

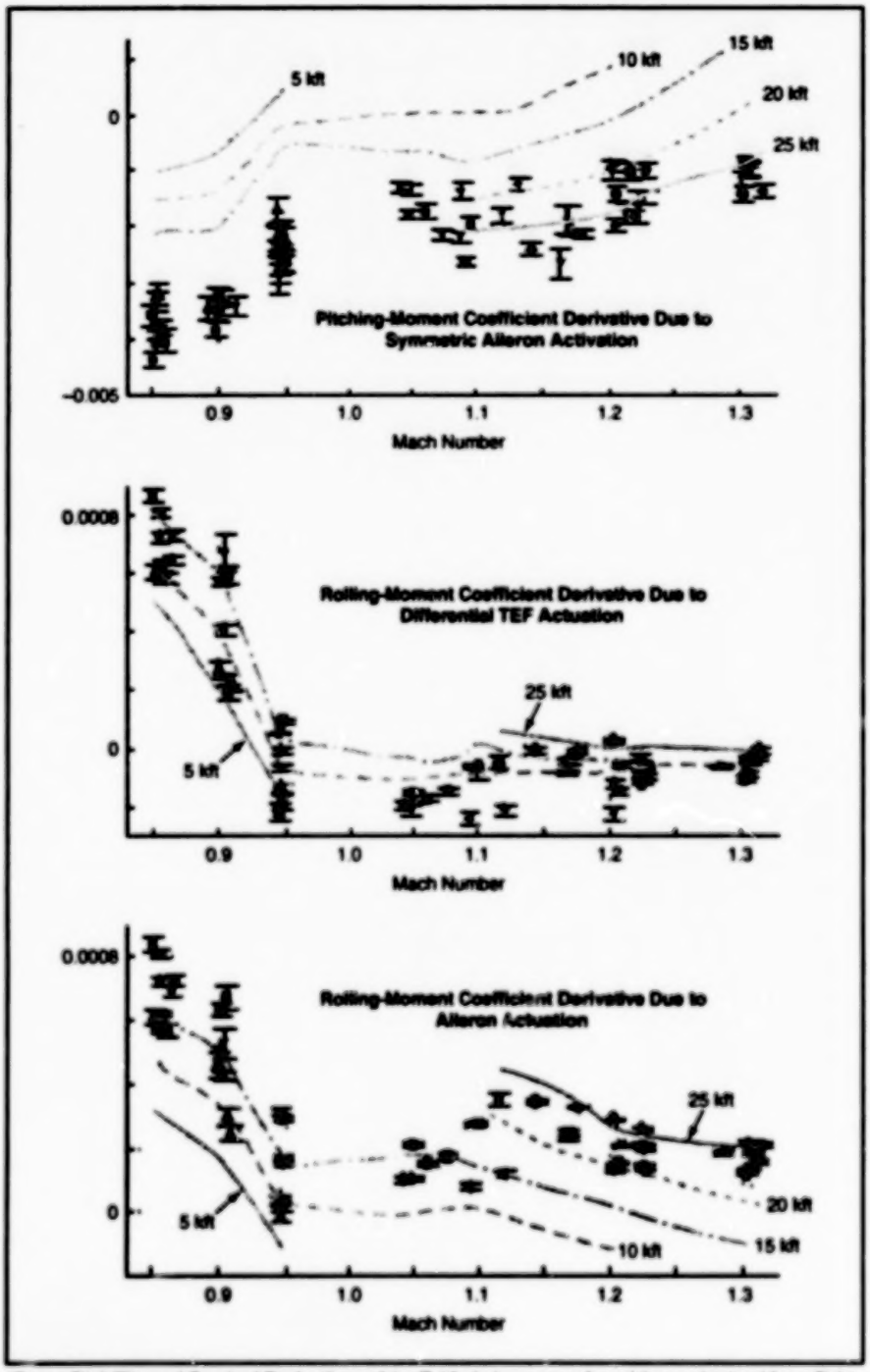
Dryden Flight Research Center, Edwards, California

Flight data gathered by use of the F-18 System Research Aircraft (SRA) based at Dryden Flight Research Center have been used to estimate stability and control derivatives for a baseline F-18 airplane. The data were obtained in the high-dynamic-pressure range of the F-18 flight envelope in an experiment performed in support of a future F-18 program to be devoted to the concept of the active aeroelastic wing (AAW). The AAW technology is intended to integrate aerodynamics, active controls, and aeroelasticity in such a way as to maximize the performance of the airplane. More specifically, the goal of the AAW project will be to maximize the contribution of a reduced-stiffness F-18 wing to roll-rate performance.

In order to support the AAW technology, changes in flight-control computers and software will be required, and an understanding of the effectiveness of each control surface under various conditions is essential. The experiment on the SRA was performed to obtain this understanding. The results of the experiment can be used to update a mathematical model of the aerodynamics of the F-18 airplane, which model can be used to improve the control laws under development for the AAW version of the F-18 airplane.

In the experiment, an onboard excitation system (OBES) was used to provide uncorrelated single-surface input (SSI) doublet sequences. Longitudinal maneuvers included leading-edge flap (LEF), trailing-edge flap (TEF), symmetric aileron, and symmetric horizontal-tail SSIs. Lateral-directional maneuvers included rudder, differential LEF, differential TEF, aileron, and differential tail SSIs. The pilot initiated each sequence of maneuvers from the cockpit and the OBES commanded the SSI doublets. During some maneuvers, the control surfaces were moved in combinations not used by the basic F-18 control laws; these included symmetric LEF, TEF, and aileron deflections at high speeds.

The data acquired during flight were analyzed afterward by use of an output-error parameter-estimation algorithm. A complete set of experimental stability and control derivatives was obtained for tests performed at 20 different combinations of mach number and altitude. A complete set of nominal control derivatives for these test conditions was also obtained from computational simulations. For example, the top part of the figure shows the effect of symmetric aileron deflection on pitching moment. In this plot, the magnitude of the experimental pitching-moment effectiveness can be seen to exceed that obtained by computational simulation, which is represented by lines for various altitudes between 5,000 and 25,000 ft (1,524 and 7,620 m), especially at low mach numbers.



These Stability and Control Derivatives of the F-18 airplane are a few of those obtained from flight-test and computational-simulation data. The lines represent the computational-simulation values for the noted altitudes.

Control-surface rolling-moment "reversal" was of special interest to the project. The middle and lower parts of the figure show TEF and aileron rolling-moment derivatives. For example TEF reversal was revealed by the flight data acquired at mach 0.95 at altitudes below 10,000 ft (3,048 m). The flight data did not reveal aileron reversal, but did show that aileron effectiveness was reduced by increasing the mach number (especially in the subsonic range) and reducing the altitude.

This work was done by Tim Moes and Gregg Noffz of **Dryden Flight Research Center**.
DRC-01-32

Ultrasonically Induced Fountains and Fogs

Diverse visual effects could be produced in computer-controlled displays.

NASA's Jet Propulsion Laboratory, Pasadena, California

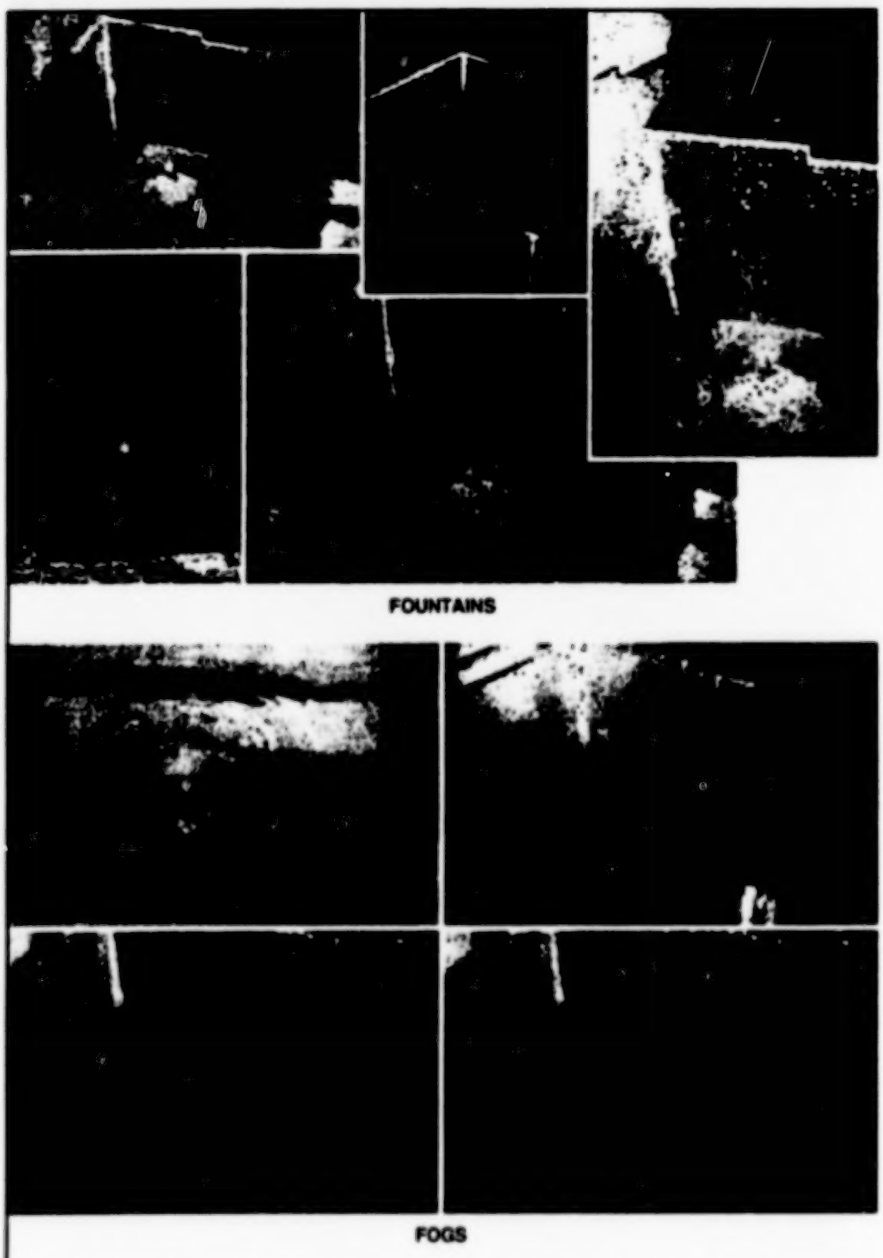


Figure 1. Fountains and Fogs were induced over a water bath by ultrasound generated by a focusing transducer immersed in the bath.

Experiments have demonstrated the feasibility of generating fountains and fogs over a body of water (see Figure 1) by utilizing high-intensity ultrasound to induce acoustic streaming, cavitation, and atomization. The transducer used in the experiments had a 10-cm diameter and a 10-cm focal length, was immersed in water at a depth approximately equal to its focal length, and was excited at various amplitudes and at various frequencies from 100 kHz to 2 MHz. It was observed in the experiments that the fountain and fog effects depend on the amplitude and frequency of excitation.

Through suitable control of the excitation waveforms applied to multiple immersed ultrasonic transducers, it should be possible to create, destroy, enlarge, diminish, or otherwise change fountains and fogs to produce diverse visual effects for artistic display. Optionally, a fountain-and-fog display generated in this manner could be synchronized with illumination and/or with music. Scattering of light from water columns, water drops, and fogs could be exploited to obtain striking visual effects.

An apparatus proposed for implementing this concept is called an ultrasonically induced plumbing-free switchable multifountains and fog (ULIFOG) system. In addition to ultrasonic transducers immersed in a water bath, a ULIFOG system (see Figure 2) would include (1) electronic circuits to excite the ultrasonic transducers with waveforms chosen to produce the desired fountain and fog effects, (2) one or more source(s) of light (e.g., lasers or colored lamps), (3) a source of music, and (4) a computer that would control the aforementioned subsystems and would coordinate the visible and audible aspects of the display.

The mechanical simplicity occasioned by elimination of the need for pipes, valves, and pumps is an advantage over prior fountain display systems. Another advantage over such systems is much faster response: For example, in an ULIFOG system, one could change a fountain into a fog in a millisecond by switching the frequency of excitation of the applicable transducer.

This work was done by Yoseph Bar-Cohen and Stacey Walker of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
NPO-21064

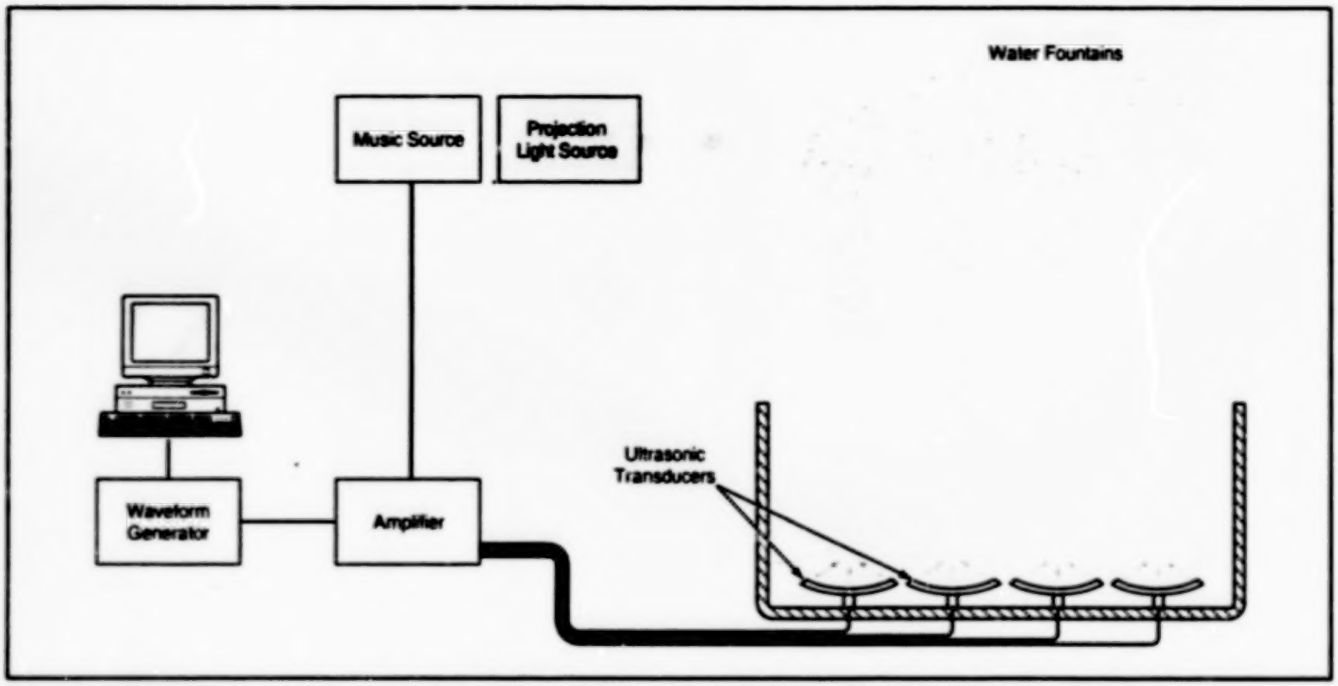


Figure 2. A ULIFOG System would exploit effects like those of Figure 1 in synchronism with lighting and sound effects.

Computational Test Cases for Oscillating Clipped Delta Wing

These data can be used to test computational simulations of aerodynamic behavior.

Langley Research Center, Hampton, Virginia

Computational test cases have been selected from archived sets of data acquired some years ago in wind-tunnel experiments on a clipped delta wing equipped with a hydraulically actuated trailing-edge control surface. In some of the experiments, the wing was subjected to pitching oscillations and control-surface oscillations. (The wing was stiff and thus did not undergo appreciable elastic oscillations; instead, it was mounted in such a way as to enable it to oscillate as a rigid torsionally sprung body.) The data obtained in the experiments included the static pressures and the real and imaginary parts of the first harmonics of dynamic pressures at a number of points on the upper and lower wing surfaces.

The significance of the experiments and the computational test cases lies in the design of the wing and in the need for experimental data to verify computational fluid dynamics (CFD) programs for use in analyzing and designing similar wings. The planform of the wing was derived by simplifying the planform of a proposed design for a supersonic transport airplane. A strake was deleted, the resulting planform was approximated by a trapezoid with an unswept trailing edge, and the twist and camber were removed. To facilitate pressure instrumentation, the thickness of the wing was increased to 6 percent of chord, as compared with 2.5 to 3 percent for the supersonic transport. The airfoil as thus designed had a symmetrical circular-arc section.

One of the consequences of increasing the relative thickness of a clipped delta wing is that transonic effects are enhanced for mach numbers near one; these effects are significantly stronger than would be the case for the thinner supersonic-transport wing. Also, the combination of the high (50.5°) leading-edge sweep and the sharpness of the leading edge results in the formation of a leading-edge vortex on the wing at relatively low (of the order of 3°) angles of attack. In addition, a shock develops over the aft portion of the wing at transonic speeds such that at some angles of attack, there is both a leading-edge vortex and a shock wave on the wing. Such cases pose a computational challenge.

The particular selection of test cases was made to illustrate trends for a variety of static, pitching-oscillation, and control-surface-oscillation conditions, with emphasis on effects associated with transonic flows. The dynamic cases were chosen for evaluation of unsteady effects under the corresponding nominally static conditions. The selection provides for parametric variation of the static angle of attack, frequency of pitching oscillation, frequency of control-surface oscillation, and mach numbers from subsonic to low supersonic values.

This work was done by Robert M. Bennett and Charlotte E. Walker of **Langley Research Center**. *Further information is contained in a TSP [see page 1].*

L-17822

Machinery

Hardware, Techniques, and Processes

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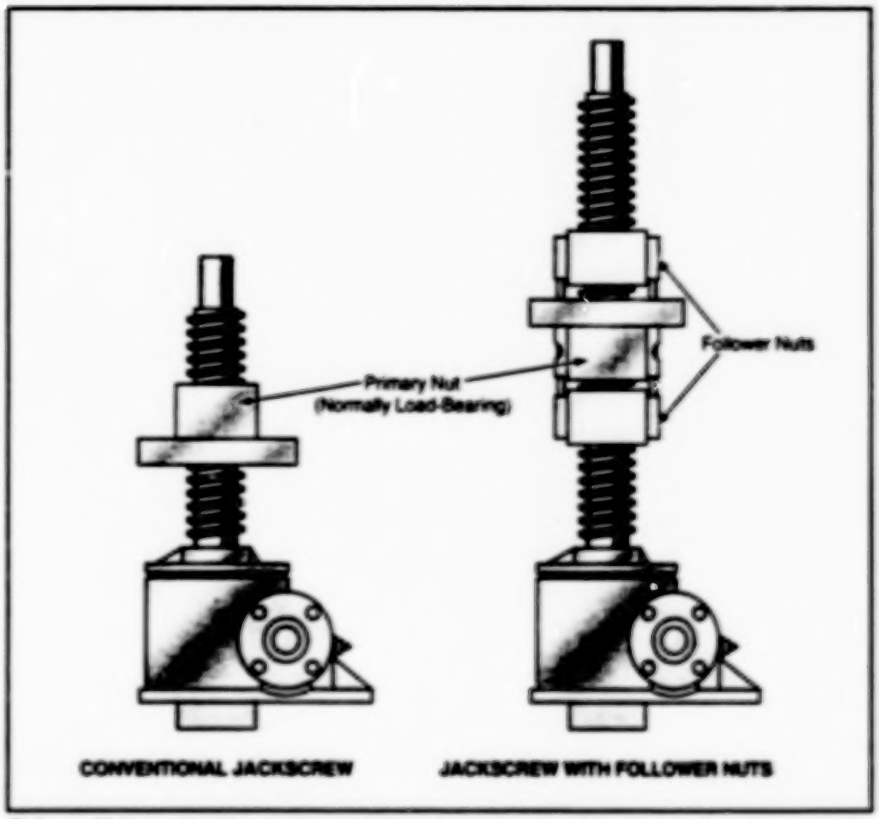
Fail-Safe, Continue-to-Operate Concept for Jackscrews

Redundant nut increases reliability and facilitates inspections.

John F. Kennedy Space Center, Florida

A fail-safe, continue-to-operate design concept for machine jackscrews calls for the incorporation of a redundant follower nut that would assume the axial jack load upon failure of the primary nut. Heretofore, the way to design for increased reliability of jackscrews has been to provide for multiple jackscrews operating in unison. The present fail-safe, continue-to-operate design concept offers an alternative for preventing catastrophic failures in jackscrews, which are used widely in aeronautical, aerospace, and industrial applications.

A conventional jackscrew contains only one nut made of a material softer than that of the threaded shaft. With prolonged use, the thread in the nut wears away. If not inspected and replaced when wear becomes excessive, the nut eventually fails by shearing of the thread under load. A typical jackscrew according to the present fail-safe, continue-to-operate concept would include a redundant follower nut in addition to the primary nut. The follower nut is mechanically attached to the primary nut and free to move axially relative to the primary nut. The follower nut would bear no axial load and would have negligible wear as long as the primary nut continued to function normally.



Follower Nuts would add protective redundancy. Upon shearing of the thread in the primary nut, the primary nut would push against one of the follower nuts, causing that nut to bear the load.

In the absence of thread wear and play, the follower nut would be axially separated from the primary nut by a distance comparable to the thread pitch. Increasing wear would cause a change in this distance that would be taken as an indication of the amount of wear prior to failure of the primary nut. The redundant follower nut assumes the axial load in the event of primary nut wear and subsequent thread shear failure. Hence, the jackscrew would continue to operate with the follower nut bearing the load until a repair could be made.

Unlike the case of a conventional jackscrew, it would not be necessary to relieve the load to measure axial play or disassemble the nut from the threaded shaft to inspect for wear. Instead, wear could be determined by measuring the axial gap between the primary and follower nut. This could be accomplished by visual inspection, or possibly with the help of a simple measuring tool. Another option could incorporate electronic or mechanical wear indicators to monitor the gap during operation and assist during inspection. These devices would be designed to generate a warning when the thread was worn to a predetermined thickness. Note: A half-thickness value is the wear tolerance recommended by major manufacturers of jackscrews.

The fail-safe, continue-to-operate concept applies to all types of machine jackscrew designs. It can be applied equally well to ball screw jacks.

This work was done by John G. Fraley, Ivan Velez, and Charles G. Stevenson of **Kennedy Space Center** *and Richard T. Ring, Jr., and Ralph Webber of United Space Alliance. Further information is contained in a TSP [see page 1].*

KSC-12187/291/92

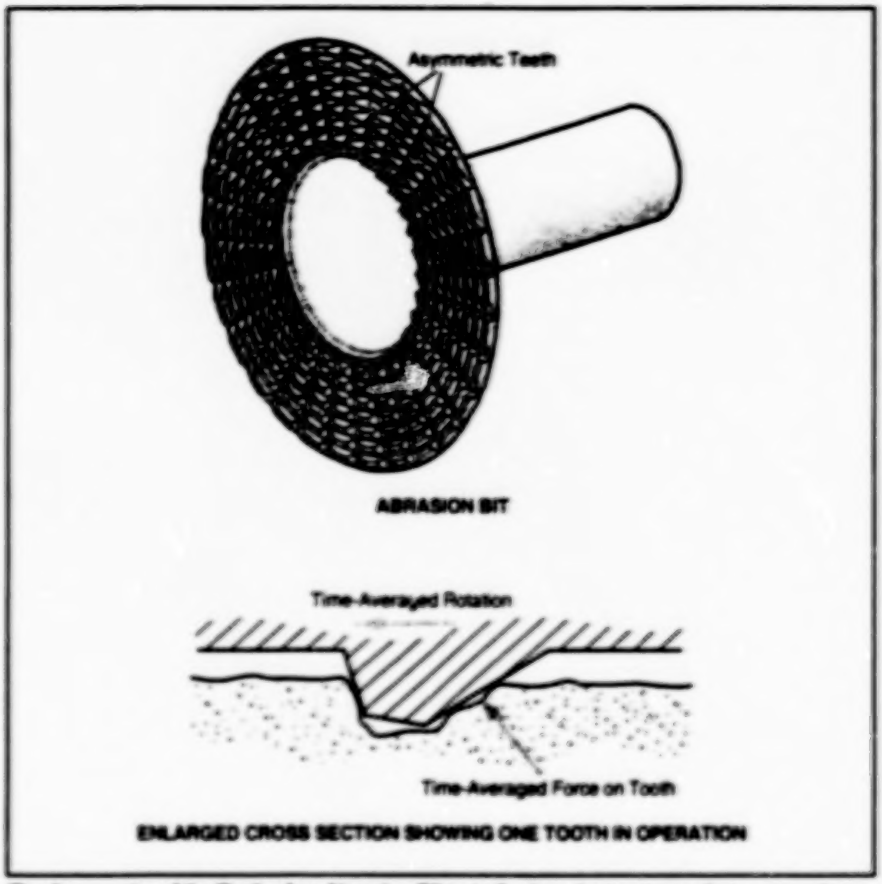
Ultrasonic/Sonic Vibrating/Rotating Tool Bits

Teeth are made asymmetric to induce rotation without need for rotary actuators.

NASA's Jet Propulsion Laboratory, Pasadena, California

An easy-to-implement design concept shows promise for improving the performances of impact tool bits used in abrading surfaces, drilling, and coring of rock and rocklike materials. The concept is especially applicable to tools actuated with a combination of ultrasonic and sonic vibrations, as in the cases described in "Ultrasonic/Sonic Drill/Corers With Integrated Sensors (NPO-20856), *NASA Tech Briefs*, Vol. 25, No. 1 (January 2001), page 38. Such tools were originally intended to be used in scientific drilling and coring of rock; they might also be useful for drilling, coring, and surface grinding of rock for art and construction.

When teeth of a tool of this type are symmetric, the tool tends not to rotate. In the absence of rotation, the hammering action



The Asymmetry of the Teeth of an Abrasion Bit typically gives rise to a torque that, averaged over time, causes the bit to rotate as indicated. On hard rock, the direction of rotation could change to the opposite of that shown here.

of the tool against the rock face causes the tool to dig a footprint that includes holes that mate with the teeth. A footprint is generally undesired for two reasons: (1) usually, one seeks uniformity of the abraded or drilled surface; and (2) once the tool settles into the footprint, the impact forces become spread over the tooth and footprint surfaces, with consequent reductions in tooth impact stresses and, hence, reduction in the rate of removal of rock.

The present design concept is simply to make the teeth asymmetric, so that the hammering action of the tool against the rock face gives rise to a net torque that causes the tool to rotate, even in the absence of a rotary actuator (see figure). The rotation prevents the formation of a footprint, thereby helping to ensure that contact between the tool and the rock takes place predominantly at the tooth tips, with consequent concentration of impact forces at tooth tips and, hence, higher impact stresses resulting in a greater rate of removal of rock.

This work was done by Benjamin Dolgin, Stewart Sherrit, Yoseph Bar-Cohen, Stephen Askins, Deborah Sigel, Xiaoqi Bao, and Zensheu Chang of Caltech for ***NASA's Jet Propulsion Laboratory****. Further information is contained in a TSP [see page 1].*
NPO-30370

Pulse-Tube Refrigerator for Liquid Hydrogen

An unusually high operating frequency enables reductions of size and weight.

Marshall Space Flight Center, Alabama

An improved closed-loop, two-stage pulse-tube refrigerator provides 4 W of cooling power at a temperature of 15 K. The original intended application of this refrigerator is in preventing boiloff of liquid hydrogen from a propellant tank aboard a spacecraft. The basic refrigerator design can also be adapted to terrestrial applications like cooling superconducting electronic devices.

The design operating frequency of this pulse-tube refrigerator is 30 Hz — an order of magnitude greater than the operating frequencies of other pulse-tube refrigerators. The higher frequency makes it possible to design a compressor that is much smaller and lighter, relative to the compressors of lower-frequency pulse-tube refrigerators of similar capacity.

This work was done by W. G. Dean of Dean Applied Technology Co., Inc., for ***Marshall Space Flight Center****. Further information is contained in a TSP [see page 1].*
MFS-31617

Mathematics and Information Sciences

Hardware, Techniques, and Processes

Books and Reports

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Beacon-Based Exception Analysis for Multimissions

Automated diagnosis is advanced using several novel signal processing approaches.

NASA's Jet Propulsion Laboratory, Pasadena, California

BEAM is a method of real-time, automated analysis and diagnosis applicable to a broad class of complex electromechanical systems, including spacecraft, aircraft, and process-control systems. Some aspects of its operation were described in "Reusable Software for Autonomous Diagnosis of Complex Systems" (NPO-20803), *NASA Tech Briefs*, March 2002. Presented here is an expanded overview of the method, outlining its components and their function.

BEAM was conceived to accelerate diagnosis and to relieve human operators and ground control computers of the burden of diagnostic data collection and analysis. This is performed through a real-time fusion and analysis of system observables, including not only performance and sensor data but also knowledge of executing software and commands sent to the system. In the case of a spacecraft, BEAM would enable onboard identification of anomalous conditions, thereby obviating the need to telemeter large quantities of sensor information.

The BEAM formalism is based upon a reduction of the observables in a complex physical system to a compact set of coupled critical observables, which are tracked to analyze the state (or "health") of the system in real time. The coupled observables determine the information space of the physical system, and monitoring its invariants allows all events, responses, deterioration, anomalies, and failures to be detected and isolated with high precision. In contrast to classical model-based approaches in which one either (1) attempts to explicitly compare observed data to model predictions, or (2) relies upon a coarse operating envelope in the form of redlines, BEAM is highly adaptable and sensitive to complex nonlinear behaviors indicative of such faults.

The mathematical foundation of BEAM includes the following building blocks:

- The System Invariance Estimator (SIE) automatically constructs fundamental information invariants from multichannel data. Comparison of the invariants allows system diagnosis, identifies which observables are significant, and quantifies deviation and dependency between events.
- The Channel Coupling Operator (CCO) provides an embedded, algorithmically constructed means of relating sensed transitions and commands. This permits oversight of software executing in conjunction with the sensed hardware.
- The Data Fusion Operator (DFO) determines the proper combinations of observables to provide an instantaneous estimate of the system information state. This estimate serves as a single, event-based, health metric.
- The Variable-Fidelity Discontinuity Operator (VDO) utilizes an adaptive wavelet transformation to detect and amplify the onset of transitions or incipient faults. This operator is a highly sensitive means of performing single-channel analysis that is adaptable to very short or very long event periods.
- The Operating Map and Back-Projection Operator (BPO) represent the downlink and reconstruction elements of BEAM. The first is a compact parameter set based upon the other modules, which efficiently encapsulates specific features of fault events. This information is expanded by the BPO to allow causal reconstruction of the anomaly track.

These modules are applicable to nearly any system and can be trained using brief examples or approximations of nominal operating data. In combination these modules permit system analysis at the local and global level, and are responsive to hard faults, incipient faults, and anomalies that lie beyond the training envelope. BEAM is intended to reduce or eliminate the need for external diagnosis but also provide capability for autonomous detection and isolation of faults and degradation.

This work was done by Sandeep Gulati and Ryan Mackey of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

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Refer to NPO-20827, volume and number of this NASA Tech Briefs *issue, and the page number.*

Books and Reports

Wavelet-Based Time-Varying Models of Pilots in Control Loops

A report presents a study of the use of wavelet-based mathematical models to quantify the responses of humans in control loops. The report begins with a review of the traditional representation of manual control responses by use of transfer functions derived from Fourier transforms, which, the report notes, are not adequate to represent the temporally varying human responses observed in practice. Some basic principles and equations of wavelet transforms are presented. It is shown how wavelets and wavelet-based transforms can be used to construct models of time-varying human response: Basically, one computes the wavelet transforms of input and output signals and then computes the ratio between these transforms, yielding what the authors call a time-varying transfer function. In an experimental test, this procedure was followed in analyzing the responses of three pilots in computationally simulated airplane-pitch-control loops during simulated flights of ≈1-minute duration. The pilot models developed in these analyses showed significant changes during the course of each simulated flight. Parameters estimated from the pilot models were also observed to vary with time. These results are interpreted as supporting the further use of wavelet-transform techniques in studies of manual control.

This work was done by Martin Brenner of **Dryden Flight Research Center** *and Peter M. Thompson and David H. Klyde of Systems Technology, Inc. To obtain a copy of the report, "Wavelet-Based Time-Varying Human Operator Models," see TSPs [page 1].*
DRC-01-56

Statistical Sampling of Tide Heights Study

The goal of the study was to determine if it was possible to reduce the cost of verifying computational models of tidal waves and currents. Statistical techniques were used to determine the least number of samples required, in a given situation, to remain statistically significant, and thereby reduce overall project costs. Commercial, academic, and Federal agencies could benefit by applying these techniques, without the need to "touch" every item in the population. For example, the requirement of this project was to measure the heights and times of high and low tides at 8,000 locations for verification of computational models of tidal waves and currents. The application of the statistical techniques began with observations to determine the correctness of submitted measurement data, followed by some assumptions based on the observations. Among the assumptions were that the data were representative of data-collection techniques used at the measurement locations, that time measurements could be ignored (that is, height measurements alone would suffice), and that the height measurements were from a statistically normal distribution. Sample means and standard deviations were determined for all locations. Interval limits were determined for confidence levels of 95, 98, and 99 percent. It was found that the numbers of measurement locations needed to attain these confidence levels were 55, 78, and 96, respectively.

This work was done by Merlon M. Hines of Lockheed Martin Corp. for **Stennis Space Center**.

Inquiries concerning rights for the commercial use of this invention should be addressed to the Intellectual Property Manager, Stennis Space Center [see page 1]. Refer to SSC-00152.

Life Sciences

Hardware, Techniques, and Processes

Books and Reports

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Water-Microbiology Kit

Samples can be analyzed conveniently in the field.

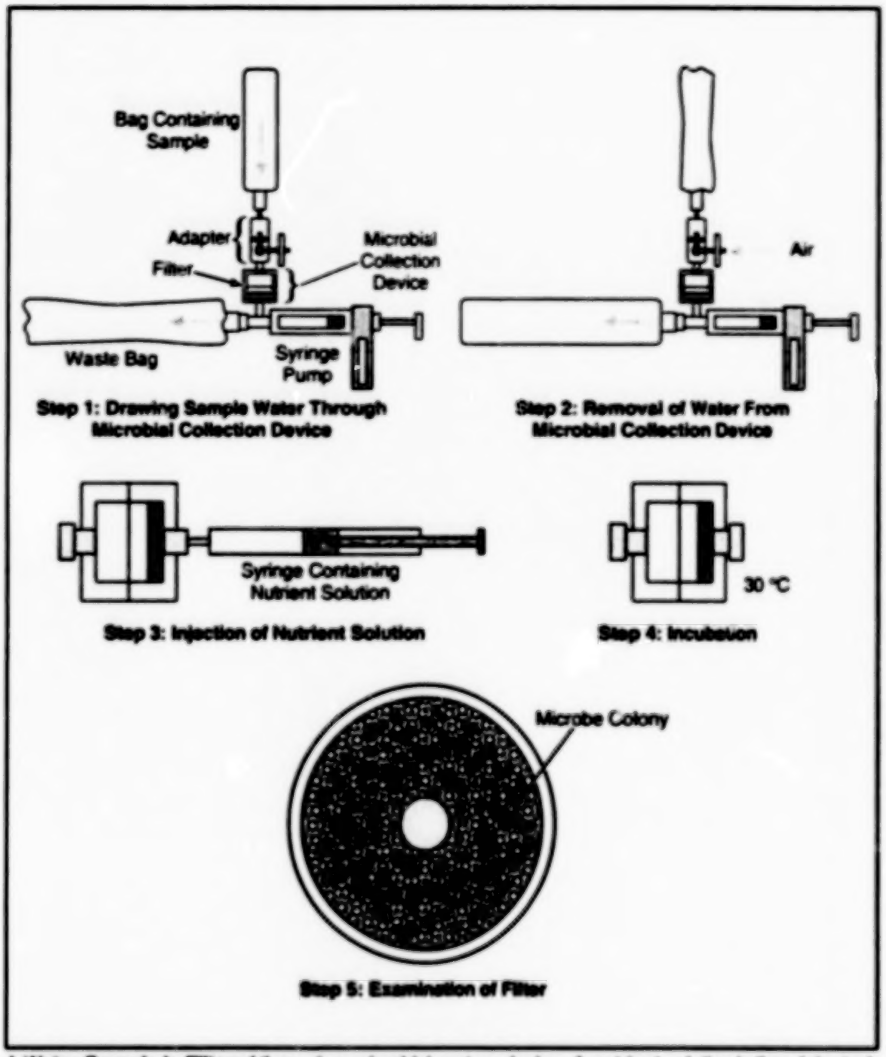
Lyndon B. Johnson Space Center, Houston, Texas

Materials and equipment for determining whether samples of potable water contain harmful microbes have been packaged in a kit. Designed for use aboard spacecraft, the kit is also suitable for terrestrial use in a laboratory or in the field. The kit holds the sample, nutrient, and waste liquids in a closed system.

The kit is based on a traditional technique that involves membrane filtration to separate microbes from the water sample, followed by growth of the microbes under favorable nutrient and temperature conditions. The resulting colonies of microbes are counted and recorded as an indication of the microbial content of the sample.

A water sample is collected in a small plastic bag. The bag is then connected to one end of an adapter unit that includes a valve. The other end of the adapter unit is connected to the inlet of a microbial capture device, which is a small in-line-filter chamber that contains (1) a cellulose acetate filter with an effective pore size of 0.45 μm and (2) an absorbent pad for subsequent retention of a nutrient solution in contact with the filter. A syringe pump and a waste bag are connected to the outlet of the microbial capture device; the syringe pump is used to draw sample water from the collection bag through the filter and into a waste bag (see figure). As sample water flows through the filter, microbes from the water become trapped in the filter.

Once the specified amount of sample water (typically, 100 mL) has been drawn through the filter, the microbial capture device is disconnected from the other devices. The nutrient solution, which is prepackaged in a syringe, is injected into the microbial collection device, which is then placed in an incubator at a temperature of 30 °C, or else left at room temperature, if an incubator is not available. After incubation for 48 h at 30 °C or 72 to 96 h at room temperature, the filter is examined; the number of bacterial colonies (which appear as blue dots) is counted and recorded.



A Water Sample Is Filtered through a microbial capture device. A nutrient solution is then injected into the device, and the device is incubated. After incubation, the number of colonies that grew from the captured microbes is counted.

This work was done by Duane L. Pierson and Richard L. Sauer of **Johnson Space Center** *and David W. Koenig, D. Bell-Robinson, S. M. Johnson, and Saroj K. Mishra of Krug Life Sciences, Inc. Further information is contained in a TSP* *[see page 1]*.

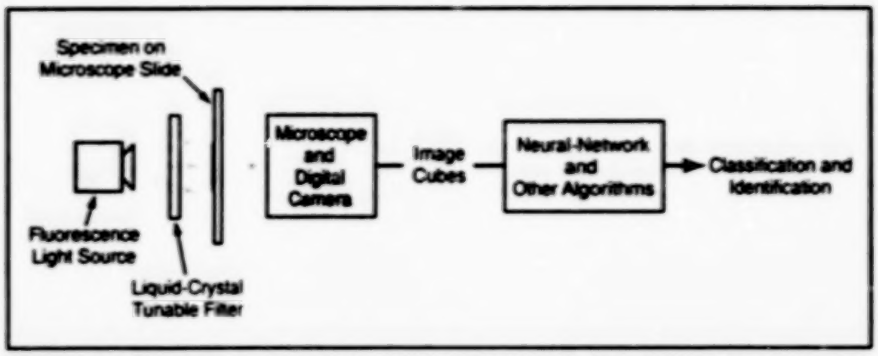
MSC-22678

Analyzing Multispectral Signatures and Images of Biomaterials Through Neural Computing

Automated analysis can save time, reduce fatigue, and increase accuracy.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of semiautomated identification of biomaterials, now under development, is based on the use of a combination of neural-network and of self-organizing, molecular, and supervised-learning algorithms to analyze multispectral images. The method is especially applicable to such biomaterials as tissues and cells depicted in multispectral images of biopsy specimens. A basic premise of this method is that tissues and cells that are or may be malignant can be distinguished from healthy cells by



Images of a Specimen are acquired in multiple spectral bands, then digitized, then processed by neural-network and other algorithms to identify portions that merit scrutiny by a human expert.

morphological and molecular differences that manifest themselves as observable differences in multispectral images.

Heretofore, it has been necessary for a pathologist to look at all the cells in a biopsy specimen under a microscope in order to determine the degree of malignancy. This examination process is fatiguing, and most cells in a typical specimen are not malignant; as a result, the process is time-consuming and usually results in many errors. An automation method like this one could reduce examination time and fatigue while increasing the accuracy of diagnosis by quickly analyzing an entire specimen and identifying those portions of the specimen to which the pathologist's attention and expertise could be applied most productively.

The figure depicts the major steps of the analysis process according to this method. A specimen is first placed on a microscope slide. Under an epifluorescence microscope, the specimen is exposed to light in a wavelength band selected by means of a liquid-crystal tunable filter. At present, transmission images of a specimen in approximately fifty 5-nm-wide wavelength bands that span the range from 470 to 710 nm. (In future versions, the wavelength range may be divided into a greater number of narrower bands.) The image in each wavelength band is detected and digitized (at present, to 12 bits for each pixel) by a monochrome digitizing electronic camera. The resulting multispectral image data can be represented as a stack of the images in the various wavelength bands; in the art of multispectral imaging, such a stack, or the data that it represents, is denoted an image cube.

For the purpose of identifying portions of an image that merit a pathologist's attention to determine the degree of malignancy, an image cube is processed by a number of algorithms, some of which implement artificial neural networks:

- The image cube is mathematically filtered to extract salient features, including sizes, shapes, and orientations of cell nuclei.
- The unsupervised-self-organizing attribute of neural networks is exploited to partition the image cube into classes based on similarities among spectral bands in the pixels.
- A combination of the self-organizing and supervised-learning attributes of neural networks is exploited to enable the use of a complex database of image cubes of known benign and malignant cells as a guide to further classification of unknown cells.

Development efforts have included the creation of a database of image cubes of known benign and cancerous human prostate cells. In tests thus far, the method as applied to image cubes of unknown prostate cells yielded correct classification in 98 percent of the cases.

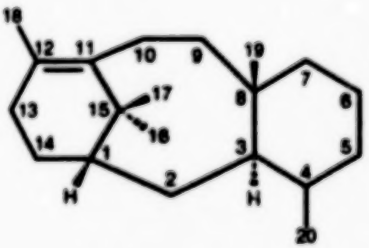
This work was done by Hamid S. Kohen of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP [see page 1].*
NPO-30265

Enhanced Bioproduction and Extraction of Taxanes

Potential anticancer drugs can be produced without destroying endangered trees.

Lyndon B. Johnson Space Center, Houston, Texas

Several groups of methods of enhanced bioproduction and extraction of taxanes have been invented. Taxanes (see figure) have exhibited potential as drugs for treatment of cancer and congenital polycystic kidney disease. One taxane — paclitaxel (more widely known under the trade name Taxol™) — has been approved by the Food and Drug Administration for treatment of several types of cancer. Currently, paclitaxel and other taxanes are produced by extraction and by semisynthesis from precursor taxanes isolated from *Taxus* sp. The present inventive methods are intended to enable the production of taxanes and related products in quantities sufficient for testing them as potential anticancer drugs, without destroying *Taxus* trees. In addition, the methods afford versatile capabilities for tailoring the chemical structures of taxanes and related products to maximize their beneficial effects.



A Taxane Molecule features a tricyclic ring nucleus. Enhanced methods of bioproduction, such as the ones described here, are needed because some taxanes are not produced naturally in the quantities needed for anticancer research and totally synthetic production currently involves too many steps to be commercially feasible.

One group of methods exploits the discovery that haploid and haploid-derived cultures of cells of any plant of the genus *Taxus* can produce taxanes. More specifically, female gametophytic tissues taken from immature seeds can be cultured to produce significant amounts of taxanes. The method of acquiring the tissues for culturing includes sterilization of seed surfaces and careful dissection to keep diploid cells (in which taxane production may in some cases be inhibited by dominant and quantitative gene interactive effects) out of the cultures. The cultures are grown under aseptic conditions that are monitored and controlled. One essential component of control is the use of culture media that do not contain nitrates. The growth process can include aging until the culture reaches a condition regarded as optimum (e.g., a condition that favors steady-state production of taxanes). Once a desired cell culture has been established, it can easily be scaled up for growth in a bioreactor to produce taxanes in larger quantities.

Taxanes can be recovered from cell cultures by one or more of methods or combi-

nations of methods, some of which were previously established, others of which are parts of the present invention. Established methods include the use of absorbent beads, the use of adsorbent particulate material released by cultured cells, and the use of solvents to extract taxanes from the aforementioned beads and particles. Methods that are parts of the present invention include enzymatic treatments, hydrolysis under suitably controlled acid or alkaline conditions, and controlled use of radiation or heat. In the cases of taxanes that are chemically bound in cells or cell fragments, such extraction may give rise to chemical alterations that could be exploited to enhance the beneficial properties of the final taxane products. In addition, alkaloids related to taxanes can be produced by the aforementioned methods.

Another group of methods, which amounts to a generalization of the aforementioned group of methods, is based on the observation that taxanes can be obtained from parts of a tree other than bark and seeds and from conifers other than those of the genus *Taxus*. These methods include (1) antibody-based screening methods to identify conifer tissues that contain taxanes and (2) taxane-recovery methods include extraction by use of solvents, enzymatic treatments, and hydrolysis.

A third group of methods, embodying a further generalization, is based on the concept of obtaining taxanes from any plant capable of producing them. This group includes antibody-based screening methods to identify taxane-producing plants, methods to isolate taxane-producing cells from cultures, methods of stimulating taxane production through control of physical and chemical conditions in cultures, and methods of extraction. Among the methods of isolating taxane-producing cells from a culture, the one that is preferred involves the use of paramagnetic beads to which are bound molecules of an antibody that recognizes another antibody that, in turn, binds taxanes that are present in or on cell walls. The cells thus isolated can then be cultured under controlled conditions for enhanced production of taxanes.

This work was done by Don J. Durzan and Frank F. Ventimiglia of the University of California for **Johnson Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

University of California
1111 Franklin Street, 5th Floor
Oakland, CA 94607-5200

Refer to MSC-23442/151/152, volume and number of this NASA Tech Briefs *issue, and the page number.*

Steam Sterilization of a Packed Column Without Admitting Air

A procedure has been devised for the use of steam to sterilize a water-purification cartridge, chromatographic column, or other closed packed column that is required to be kept filled with water and from which it is required to exclude air bubbles, which could impede flow. For the purpose of this procedure, the column must be equipped with valves and quick-disconnect fittings at both ends. First, the column is flushed and filled with distilled water. The outlet of the column is then connected to a tube, the other end of which is open and is placed at the bottom of a bottle partly filled with distilled water. More distilled water is flushed from the inlet, then through the column, outlet, and tube, into the bottle. The inlet valve is closed and disconnected from the source of water, the column is placed on a stand in an autoclave with the outlet valve open, and the autoclave is activated through its heating cycle. After cooldown from the heating cycle, the outlet valve is closed and disconnected from the column, which is now sterile and filled with distilled water.

This work was done by Richard L. Sauer, Duane L. Pierson, and Jose G. Limardo of **Johnson Space Center** *and David W. Koenig and Paul Mudgett of KRUG Life Sciences. Further information is contained in a TSP [see page 1].*

MSC-22760

Books and Reports

Noninvasive Assessment of Human Fine Motor Control

A report presents additional information about the Impairscope — an instrument for noninvasive measurement of fine neuromuscular control and, more particularly, for quantifying the degradation of neuromuscular performance under psychological stress. The instrument, previously called the "Neuroskill device," was described in "Biometric Instrument Measuring Neuromuscular Disorder/Performance Degradation" (MFS-26449), *NASA Tech Briefs*, November 1997. To recapitulate: The instrument includes an instrumented pen that measures motions along the two axes perpendicular to its long axis and the axial force with which the pen is pressed against a writing surface. The measurements are digitized 200 times per second and processed by software that implements an advanced method of correlation-function analysis to generate measures of the stability, smoothness, and synchronization of handwriting movements. The instant report reiterates information from the cited previous article, discusses the shortcomings of prior techniques for assessing effects of stress on motor control, briefly describes an underlying theory of the granular stationarity of the statistical properties of handwriting dynamics, and summarizes results of an experiment in which Impairscope measurements showed a degradation of handwriting performance in a group of students under the stress of final examinations.

This work was done by Ruth Shrairman and Alexander Landau of VeriFax Corp. for **Johnson Space Center**. *To obtain a copy of the report, "Non-Invasive Method For Assessment of Human Fine Motor Control," see TSPs [page 1].*

MSC-23030

END

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